



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

EDUC T 339.11.740

Harvard College Library



LIBRARY OF THE

Department of Education

COLLECTION OF TEXT-BOOKS

Contributed by the Publishers

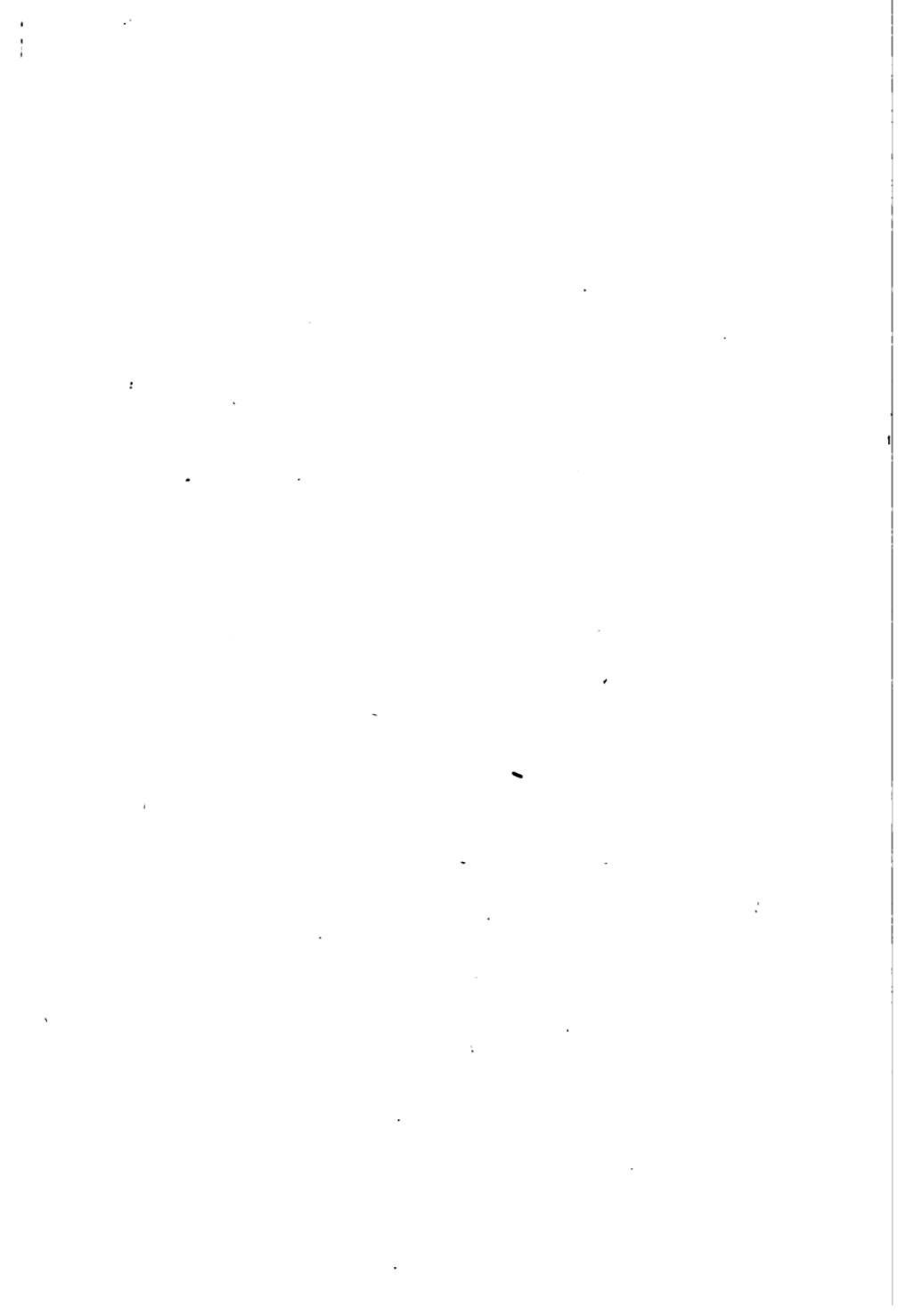
TRANSFERRED

TO

HARVARD COLLEGE
LIBRARY



3 2044 097 024 855



INTRODUCTION TO GENERAL SCIENCE

Harvard University
Dept. of Education Library
Gift of the Publisher



THE MACMILLAN COMPANY
NEW YORK • BOSTON • CHICAGO
SAN FRANCISCO

MACMILLAN & CO., LIMITED
LONDON • BOMBAY • CALCUTTA
MELBOURNE

THE MACMILLAN CO. OF CANADA, LTD.
TORONTO

INTRODUCTION
TO
GENERAL SCIENCE
WITH EXPERIMENTS

BY
PERCY E. ROWELL, B.Sc.

New York
THE MACMILLAN COMPANY
1911

All rights reserved

~~T29.7803~~

EdueT 339.11.740

↓

May 20, 1912.
Harvard University
Dept. of Education Library
Gift of the Publishers

TRANSFERRED TO
HARVARD COLLEGE LIBRARY
APR 25 1921

COPYRIGHT, 1911,
BY THE MACMILLAN COMPANY.

Set up and electrotyped. Published August, 1911. Reprinted
September, November, 1911.

Norwood Press
J. S. Cushing Co. — Berwick & Smith Co.
Norwood, Mass., U.S.A.

To
MY MOTHER

PREFACE

HOWEVER much we may theorize, and try to impress the youth with the proper conception of man's place in nature, the individual young person will continue to consider himself as the center of the universe. Immediate needs and close-surroundings are what interest him. It is not until he has learned about these, and has followed back to their sources and causes some of the phenomena which have seemed simple and matter of fact, that he begins to realize that the distant forces have more effect upon his existence than the near-by, everyday happenings. Perhaps it is well, then, at the beginning of science study, to take his point of view, and lead him to follow each apparently simple need or desire, and to arouse in him the habit of seeking for a cause, and looking beyond the present and immediate to the future and the ultimate. It may be truly said that in a General Science course, "All roads lead to Rome," for the course may be commenced anywhere, and it will lead to a study of all science. In fact, if the pun may be forgiven, in a General Science course, "All roads lead to roam," and the pupil, after he is started, needs but to be guided. That is the purpose of this book.

It is not easy to teach a course in general science successfully. There is always the temptation to specialize in some particular part, usually the part which the teacher likes best, and about which he knows most. If this temptation is not resisted, the course ceases to be general.

The value of a General Science course is twofold. Knowing a little about a great many sciences enables the pupil to

obtain a bird's-eye view of all, and a day's lesson in some one of the elementary sciences ceases to be a blind alley, or a path which must be followed with complete faith that the teacher knows where it will lead. The pupil can see the interrelation of all sciences, and can reason from many points of view.

2. The other value lies in awakening the mind to the vast possibilities of scientific knowledge and mental attainments. A course in general science should reach every pupil in at least one science and stimulate his ambition to learn more of it. If this be true, we must have two purposes in the presentation of such a course,—to overcome narrowness, and to stimulate ambition.

If there is not a definite plan for the year's work, a goal toward which the class is to strive, there must be waste of time and loss of interest. This book is offered in the hope that it may aid and guide the teacher, as well as help the pupils, always allowing for initiative on the part of both. Such a course is elastic and can never be limited by an outline, however full. While a large proportion of the experiments are standard, it has been the author's endeavor to require simple apparatus and chiefly qualitative work. Several of the experiments are believed to be new, and the element of play has been brought in wherever it seemed feasible. The numbering of the reference books is arbitrary, but must necessarily be so, as the Dewey system is not sufficiently graduated for exact reference. Local conditions should by all means be emphasized, for, to be valuable, the course must touch the lives of the pupils in as many places as possible.

The book may be used without any of the reference books except the publications of the United States government. However, the references have been divided into two groups: one contains fourteen books for general supplementary work;

the other comprises seventy-four books, so chosen as to enable the instructor to emphasize any particular branch of science. It is not intended that all of the references be utilized. The General Science course should be adapted to the locality. It is easier for the teacher to select what is wanted, from a sufficiently large list, than it is to hunt for material outside of the references.

In addition to these library books, the list of the publications of the United States Department of Agriculture is quite large and the number of references to them considerable. New publications are constantly appearing, and the teacher may add to this list indefinitely. The pupils should be urged to get the "bulletin habit."

I wish to thank the publishers of the books to which I have referred for their kindness and coöperation, and the teachers who have supplied me with valuable suggestions. Especially do I wish to express my appreciation to Mr. Allan B. Campbell for his assistance, without which the appearance of the book this year would have been impossible. To one other, however, the greatest credit is due, for her assistance extends back through many patient years, and without her stimulating influence the ability to gather together the facts contained in this outline would have been an impossibility at any time. To her this book is dedicated.

PERCY ELLIOTT ROWELL.

Los ANGELES, CALIFORNIA,
July, 1911.



CONTENTS

SECTION	PAGE
1. Explosions	1
2. Composition of Matter—Definition of Heat	2
3. States of Matter	3
4. Combustion	5
5. Oxygen—Its Uses and Action	8
6. Fuels	10
7. Blasting	11
8. Gas and Gasoline Engines	11
9. Animal Heat	12
10. Flames	14
11. First Aid to the Burnt	15
12. Sterilization by Heat	16
13. Antiseptic Washes—Disinfectants	17
14. Chemical Effects of Heat	19
15. Expansion Due to Heat	19
16. Temperature and its Measurement	21
17. Conduction	23
18. Convection	24
19. Ventilation and Heating of Buildings	26
20. Radiation of Heat	27
21. Absorption of Heat	28
22. Measurement of Heat	30
23. Heat of Change of State	31
24. Evaporation Requires Heat	34
25. Applications of Evaporation and Condensation	35
26. The Steam Engine	38
27. Distillation of Liquids	38
28. Destructive Distillation	40
29. Cooking	42
30. Chemical and Physical Changes	44
31. Chemical Combination Produces Heat	46
32. Friction and Compression Produce Heat	47

SECTION	PAGE
33. Kadium Produces Heat	49
34. The Sun	50
35. The Sun the Source of All Energy	51
36. Theories	52
37. The Laws of Motion	53
38. Effects of Two or More Forces Acting at the Same Time	55
39. Universal Gravitation	56
40. The Center of Gravity	57
41. The Effect of Two Forces Acting at Right Angles to Each Other	58
42. The Measurement of Rotary Motion	59
43. Theories of the Evolution of the Solar System	61
44. The Solar System	63
45. The Planets and the Earth	63
46. Age of the Earth	65
47. The Shape and Size of the Earth	65
48. The Heat of the Earth	67
49. Direction—Latitude and Longitude	68
50. Motions of the Earth	69
51. Time	71
52. The Seasons	72
53. The Calendar	74
54. The Moon	75
55. Tides	76
56. Meteors	77
57. Comets	78
58. The Stars	79
59. Distances of the Stars	80
60. The Earth as a Whole	80
61. The Earth as a Magnet	81
62. Other Magnets	83
63. The Northern Lights	85
64. Sources of Electricity	86
65. Applications of Electricity	88
66. Chemical Effects of Electricity	90
67. Heat and Light from Electricity	91
68. Heat Produces Light	94
69. Light and Vision	95
70. Reflection	96

SECTION	PAGE
71. Color	98
72. Refraction and Dispersion	100
73. The Rainbow	101
74. Diffusion of Light	102
75. Twilight	103
76. Transmission of Light—Shadows	104
77. Eclipses	104
78. Measurement of Light	105
79. Photography	107
80. The Atmosphere and its Composition	109
81. Weight of the Air	110
82. Atmospheric Pressure and the Barometer	112
83. Boiling from Another Point of View	114
84. "Suction"	115
85. Pumps	116
86. The Siphon	117
87. Nitrogen and its Uses	118
88. Effects of Painting—Wood Preservation	120
89. Carbon Dioxide	122
90. The Chemical Engine	124
91. Other Constituents of the Atmosphere	125
92. Atmospheric Electricity	126
93. Warming the Air	127
94. Winds	128
95. Kinds of Winds	129
96. Velocity of Winds	130
97. Resolution of Forces	131
98. The Theory of the Kite	133
99. The Theory of the Aéroplane	135
100. Sailing a Boat	137
101. Humidity	138
102. Dew	139
103. Frost	141
104. Fog and Clouds	142
105. Snow and Hail	143
106. Rainfall—Cyclones	144
107. Weather Observations	146
108. Weather and Climate	148
109. Weather Instruments	149

SECTION		PAGE
110. Home-made Weather Instruments	.	150
111. The Ocean	.	150
112. Purification of Water	.	152
113. Springs and Streams	.	155
114. Composition of Water	.	156
115. Solution and its Effects	.	157
116. Uses of Water	.	160
117. Surface Tension	.	162
118. Capillarity	.	164
119. Osmosis	.	166
120. Removal of Grease Spots and Stains	.	168
121. Acids, Bases, and Salts — Neutralization	.	170
122. Hygroscopic and Efflorescent Salts	.	173
123. Soap	.	174
124. Hard Water	.	176
125. The Earth's Crust	.	177
126. Changes in the Surface of the Earth	.	178
127. Weathering and the Rate of Weathering	.	179
128. Agents of Weathering	.	180
129. Erosion	.	182
130. Agents of Erosion	.	183
131. Disintegration Due to Plant and Animal Life — Bacteria	.	184
132. Slowness of Change	.	185
133. Rocks Defined and Classified	.	186
134. The Difference between Minerals and Rocks	.	187
135. Rocks of the Earth's Crust	.	188
136. Organic Rocks	.	191
137. Coal, Soft and Hard	.	192
138. Petroleum and Natural Gas	.	194
139. How Mountains are Made	.	195
140. The Source of Food — The Soil	.	196
141. The Farm a Workshop	.	197
142. Resources of the Soil	.	199
143. Kinds of Soil	.	200
144. Transportation of Soils	.	201
145. Texture of the Soil	.	202
146. Importance of Moisture	.	204
147. How Water is Held in the Soil	.	205
148. To Increase the Moisture-holding Capacity — Tilling	.	206

SECTION	PAGE
149. Conservation of Moisture—Tilling	207
150. Irrigation and Underdrainage	210
151. Soil Air	212
152. Plant Food—I	213
153. Humus	215
154. Enriching the Soil	216
155. Green Manures	217
156. Barnyard Manure	218
157. Renovation of Worn-out Soils	220
158. The Liming of the Soil	220
159. Commercial Fertilizers	222
160. Use of Commercial Fertilizers	223
161. Home-mixed Fertilizers	224
162. Fertilizers for Garden Crops	225
163. Plant Roots	226
164. Plant Stems	227
165. Leaves	228
166. Buds	230
167. Flowers	231
168. Fruits and Seeds	232
169. Flavoring Extracts and Perfumes	234
170. Plant Food—II	235
171. The Propagation and Breeding of Plants	236
172. Plants—Forestry	237
173. Lower Forms of Plant Life—Bacteria, Molds, and Mildew	238
174. Fermentation—Yeast	240
175. Alcohol for Purposes of Energy	241
176. Lower Forms of Plant Life—Fungi, Rusts, Mushrooms, etc.	243
177. Protozoa and Amœbæ	244
178. Insects and the Smaller Animals	245
179. The Stings of Insects	246
180. Animal Life—Distribution	247
181. The Invertebrates	247
182. Animal Life—Fishes, Animals, and Birds	248
183. Animal Life—Man	249
184. The Life Processes	250
185. The Bones, or Framework	251
186. The Lever and its Advantage	252

SECTION	PAGE
187. The Muscles	254
188. The Blood	255
189. Respiration	255
190. Dangers of Vitiated Air	257
191. Food and Nutrition	259
192. Digestion	260
193. Food—Vegetable Food	262
194. Food—Animal Food	263
195. Food Analysis	264
196. Water Analysis	268
197. Food—Preservation of Food	270
198. The Mind	271
199. The Senses—Sight	272
200. Sound and Hearing	274
201. Man's Place in Nature	277
202. Nature and Business	278
203. Man's Applications of Nature's Principles	279
204. How to Plan a House and Barn	280
205. Conveniences for the Home	282
206. Sanitation	284
207. Sanitary Plumbing	285
208. Simple Household Remedies	287
209. Reading Meters	290
210. Economy	291
211. Education and Civilization	293
212. Manner of Living	294

LIST OF EXPERIMENTS

SECTION	PAGE
1. Experiments for the Teacher	1
2. Experiments for the Teacher (in reference book 1803)	3
4. Expt. 1. Ordinary Combustion	5
Expt. 2. Spontaneous Combustion	6
5. Expt. 3. Oxygen and Combustion	8
9. Expt. 4. Complete and Incomplete Combustion	13
10. Expt. 5. Source of Flames	15
15. Expt. 6. Expansion Due to Heat	20
16. Expt. 7. The Fixed Points of the Thermometer	22
17. Expt. 8. Conduction	23
18. Expt. 9. Convection in Gases	25
Expt. 10. Convection in Water	25
20. Expt. 11. Radiation of Heat	28
21. Expt. 12. Absorption of Heat	30
22. Expt. 13. Quantity of Heat Comparison	31
23. Expt. 14. Heat of Change of State	33
25. Expt. 15. Cooling by Evaporation	37
Expt. 16. Heating by Condensation	37
27. Expt. 17. Distillation	39
28. Expt. 18. Destructive Distillation	41
29. Experiment for the Home	44
30. Expt. 19. Physical and Chemical Changes	45
31. Experiments for the Teacher	47
32. Experiments for the Home	48
Experiment for the Teacher	49
37. Expt. 20. Inertia and Reaction	54
38. Experiment for the Teacher	55
40. Expt. 21. Center of Gravity	58
41. Experiment for the Home	59
42. Expt. 22. To Make and Use a Clinometer	60
49. Expt. 23. To Locate the North by Means of the Sun	69
Expt. 24. To Locate the South by Means of a Watch	69

SECTION		PAGE
52. Expt. 25.	The Seasons — Length of Day and Night	73
61. Expt. 26.	The Earth's Magnetism	82
62. Expt. 27.	Magnetism	84
64. Expt. 28.	Sources of Electricity	87
65. Expt. 29.	The Electric Bell, Telegraph, and Telephone	90
66. Expt. 30.	Electroplating	91
Expt. 31.	The Storage Cell	92
67. Expt. 32.	Heat and Light from Electricity	93
68. Expt. 33.	Heat Produces Light	95
70. Expt. 34.	Reflection	97
71. Expt. 35.	Color	99
72. Expt. 36.	Refraction and Dispersion	101
73. Expt. 37.	The Rainbow	102
78. Expt. 38.	Candle Power — The Photometer	106
79. Expt. 39.	Effect of Light upon a Silver Salt	108
80. Expt. 40.	Composition of Air	110
81. Expt. 41.	Weight of Air	111
82. Expt. 42.	Atmospheric Pressure	113
83. Expt. 43.	Boiling at Reduced Pressure	115
84. Expt. 44.	“Suction”	116
86. Expt. 45.	The Siphon	118
87. Expt. 46.	To Prepare Nitrogen	119
88. Expt. 47.	The Testing of Paint	121
89. Expt. 48.	Sources of Carbon Dioxide	123
90. Expt. 49.	Preparation of Carbon Dioxide — The Chemical Engine	125
97. Expt. 50.	Resolution of Forces	132
98. Expt. 51.	To Make a Malay Kite	134
99. Expt. 52.	To Make a Boomerang	136
100. Expt. 53.	To Make a Windmill	138
101. Experiment for the Teacher	for the Teacher	139
102. Expt. 54.	The Dew Point	141
105. Expt. 55.	Sublimation	144
107. Expt. 56.	Temperature Curves	147
110. Experiments for the Home	for the Home	150
112. Expt. 57.	Precipitation and Filtration	153
114. Expt. 58.	To Prepare Hydrogen	157
	Experiment for the Teacher	157
115. Expt. 59.	Solution and its Effects	159

LIST OF EXPERIMENTS

xix

SECTION		PAGE
116. Expt. 60.	Specific Gravity — Bouyancy	161
117. Expt. 61.	Surface Tension	163
118. Expt. 62.	Capillarity	165
119. Expt. 63.	Osmotic Pressure	167
120. Expt. 64.	The Removal of Stains	169
121. Expt. 65.	Acids, Bases, and Salt — Neutralization	172
122. Expt. 66.	Efflorescence and Deliquescence	174
123. Expt. 67.	To Make Soap	175
124. Expt. 68.	Temporary Hardness	177
135. Expt. 69.	Sedimentation	190
136. Expt. 70.	To Test Rocks	192
138. Expt. 71.	Distillation of Petroleum	195
145. Expt. 72.	Water Capacity of Soils	208
149. Expt. 73.	The Effect of Mulches	209
151. Experiment for the Teacher		213
	Expt. 74. Air Necessary for Roots	213
158. Expt. 75.	The Effect of Lime — Acid Soils	221
163. Expt. 76.	Effect of Roots on Soil	227
164. Expt. 77.	The Pressure of Sap	228
165. Expt. 78.	Transpiration	229
168. Expt. 79.	Seed Testing — Germination	233
169. Expt. 80.	To make Lemon Extract	234
175. Expt. 81.	Sources of Alcohol	243
186. Expt. 82.	The Lever	253
190. Expt. 83.	Test for Bad Air	258
192. Expt. 84.	Digestion of a Proteid	261
193. Expt. 85.	The Amount of Water in Vegetables	263
195. Expt. 86.	Composition of Food	265
	Expt. 87. Test for Food Preservatives and Colors	267
196. Expt. 88.	Water Analysis	269
199. Expt. 89.	Persistence of Vision — Fatigue	273
200. Expt. 90.	The Origin of Sound — Music	275
	Expt. 91. The Megaphone and the Mechanical Telephone	275
209. Experiments for the Home		291
210. Expt. 92.	Dyeing	293



EXPLANATION OF BOOK NUMBERING

THE numbers, as given in the list which follows, may be written on Dennison's Labels No. 539, and affixed to the back of the binding, below the title of the respective books. This must be in addition to any other system of numbering, and it may be well to number the books also on the inside of the front cover, in order to save time in case the outside labels come off.

It would be advisable to segregate the books to be used with this outline, and to arrange them according to the numbering. This plan permits the pupils to work rapidly and effectively, since they may obtain a desired book, directly by number, without hunting for title or author. Wherever this system has been established, success has marked it from the start. The starred books are those which are referred to by number, and are the most important in connection with this outline.

The publications of the United States Department of Agriculture may be obtained, free of charge, by addressing the Secretary of Agriculture, Washington, D. C. A catalogue of the publications of this department will serve as a source of valuable information, and it should be in the hands of every science teacher. It may be obtained free upon application. The teacher should have the school listed to receive the "Monthly List of Publications," which is sent free upon request.

If the teacher desires to add books to this list, the next higher number may be used, in the proper classification, and references made at the proper places in the text. Thus the book may be adapted to any locality, and may be used to guide the thoughts of the pupils in any desired direction.

NUMBERING FOR REFERENCE BOOKS

1001. Elements of Astronomy. Young. Ginn.
- *1002. Introduction to Astronomy. Moulton. Macmillan.
1003. Elements of Astronomy. Newcomb. A. B. Co.
1004. Lessons in Astronomy. Young. Ginn.
- 1005.
- 1006.
- 1007.
- 1008.
- 1009.
- 1010.
1101. Exercises in Meteorology. Ward. Macmillan.
1102. Elementary Meteorology. Davis. Ginn.
- *1103. Elementary Meteorology. Waldo. A. B. Co.
- 1104.
- 1105.
- 1106.
- 1107.
- 1108.
- 1109.
- 1110.
1201. Rocks and Minerals. Fairbanks. Educ. Pub. Co.
1202. Rocks—Weathering and Soils. Merrill. Macmillan.
1203. The Earth and Its Story. Heilprin. Silver, Burdett.
1204. Story of Our Continent. Shaler. Ginn.
- *1205. Elements of Geology. Norton. Ginn.
1206. Elementary Geology. Tarr. Macmillan.
1207. Outlines of the Earth's History. Shaler. Appleton.
1208. Common Rocks and Minerals. Crosby. Heath.
1209. Textbook of Geology. Brigham. Appleton.
1210. Compend of Geology. Le Conte. A. B. Co.

1211.
1212.
1213.
1214.
1215.
1301. First Book of Physical Geography. Tarr. Macmillan.
1302. Lessons in Physical Geography. Dryer. A. B. Co.
1303. Elementary Physical Geography. Davis. Ginn.
*1304. New Physical Geography. Tarr. Macmillan.
1305. Eclectic Physical Geography. Hinman. A. B. Co.
1306. Elementary Physical Geography. Tarr. Macmillan.
1307. Elementary Physical Geography. Redway. Scribners.
1308. Physical and Commercial Geography. Gregory, Keller, Bishop.
Ginn.
1309. Physical Geography. Maury-Simonds. A. B. Co.
1310. Physical Geography. Salisbury. Holt.
1311. Introduction to Physical Geography. Gilbert, Brigham. Ap-
pleton.
1312. Elements of Physical Geography. Hopkins. Sanborn.
1313. A Reader in Physical Geography. Dodge. Longmans.
1314.
1315.
1401. The Foundations of Botany. Bergen. Ginn.
1402. Botany. Bailey. Macmillan.
1403. First Lessons with Plants. Bailey. Macmillan.
1404. Experiments with Plants. Osterhout. Macmillan.
1405. Elements of Botany. Bergen. Ginn.
1406. Botany All the Year. Andrews. A. B. Co.
*1407. Principles of Botany. Bergen-Davis. Ginn.
1408.
1409.
1410.
*1501. Applied Physiology. Overton. A. B. Co.
1502. Nature Study and Life. Hodge. Ginn.
*1503. Elements of Biology. Hunter. A. B. Co.
1504. Elementary Biology. Parker. Macmillan.
1505. First Course in Biology. Bailey, Coleman. Macmillan.
1506. Human Body and Health. Davison. A. B. Co.
1507. Advanced Physiology and Hygiene. Conn and Budington.
Silver, Burdett.

- 1508. Animal Activities. French. Longmans.
- 1509. Principles of Physiology and Hygiene. Fitz. Holt.
- 1510. Physiology of Man. Moore. Holt.
- 1511. Academic Physiology and Hygiene. Brands. Sanborn.
- 1512. Zoölogy, Descriptive and Practical. Colton. Heath.
- 1513.
- 1514.
- 1515.
- *1601. The Soil. King. Macmillan.
- 1602. First Principles of Agriculture. Goff and Mayne. A. B. Co.
- 1603. Agriculture for Beginners. Burkett, Stevens, Hill. Ginn.
- 1604. The Great World Farm. Gaye. Macmillan.
- *1605. Elements of Agriculture. Warreh. Macmillan.
- 1606. Principles of Agriculture. Bailey. Macmillan.
- 1607. Physics of Agriculture. King. King.
- 1608. Practical Agriculture. Wilkinson. A. B. Co.
- 1609. How Crops Grow. Johnson. Judd.
- 1610. First Principles of Agriculture. Voorhies. Silver, Burdett.
- 1611. Agriculture, Pacific Slope. Hilgard and Osterhout. Macmillan.
- 1612. Soils. Burkett. Orange Judd.
- 1613.
- 1614.
- 1615.
- 1701. Elementary Study of Chemistry. McPherson and Henderson. Ginn.
- *1702. Chemistry of Plant and Animal Life. Snyder. Macmillan.
- *1703. Essentials of Chemistry. Hessler and Smith. Sanborn.
- 1704. Manual of Chemistry. Storer and Lindsay. A. B. Co.
- 1705. Elementary Experimental Chemistry. Ekeley. Silver, Burdett.
- 1706. Descriptive Chemistry. Newell. Heath.
- 1707. Chemistry (briefer). Remsen. Holt.
- 1708. Essentials of Chemistry. Williams. Ginn.
- 1709. First Principles of Chemistry. Brownlee, etc. Allyn & Bacon.
- *1710. Sanitary and Applied Chemistry. Bailey. Macmillan.
- 1711. Elementary Chemistry. Bradley. Appleton.
- 1712. Elementary Chemistry. Godfrey. Longmans.
- 1713. History of Chemistry. Venable. Heath.
- 1714.

1715.

1801. High School Physics. Carhart and Chute. Allyn & Bacon.

1802. Forty Lessons in Physics. McMullen. Holt.

*1803. First Course in Physics. Millikan and Gale. Ginn.

1804. Principles of Physics. Gage. Ginn.

1805. Physics for Secondary Schools. Adams. A. B. Co.

1806. A Textbook of Physics. Hall and Bergen. Holt.

1807. Elements of Physics. Coleman. Heath.

1808. A Brief Course in Physics. Hoadley. A. B. Co.

1809. Textbook of Physics. Linebarger. Heath.

1810. Elements of Physics. Sanford. Holt.

1811. Elementary Physics. Miller and Foerste. Scribners.

1812.

1813.

1814.

1815.

*1901. Bacteria, Yeasts, and Molds. Conn. Ginn.

1902. Agricultural Bacteriology. Conn. Blakiston.

1903. Bacteria in Relation to Country Life. Bailey. Macmillan.

1904. Primer of Sanitation. Ritchie. World.

1905. School Sanitation and Decoration. Burrage and Bailey. Heath.

1906.

1907.

1908.

1909.

1910.

**PUBLICATIONS OF THE UNITED STATES DEPARTMENT
OF AGRICULTURE**

FARMERS' BULLETINS

No. 28. Weeds and How to Kill Them.

No. 34. Meats; Composition and Cooking.

No. 44. Commercial Fertilizers.

No. 54. Some Common Birds.

No. 77. The Liming of Soils.

No. 78. Experiment Station Work; Miscellaneous.

No. 79. Experiment Station Work; Miscellaneous.

- No. 85. Fish as Food.
- No. 86. Thirty Poisonous Plants.
- No. 93. Sugar as Food.
- No. 104. Notes on Frost.
- No. 105. Experiment Station Work; Miscellaneous.
- No. 121. Beans, Peas, and Other Legumes as Food.
- No. 122. Experiment Station Work; Miscellaneous.
- No. 126. Practical Suggestions for Farm Buildings.
- No. 127. Important Insecticides.
- No. 128. Eggs and their Uses as Food.
- No. 131. Household Tests of Butter.
- No. 134. Tree Planting on Rural School Grounds.
- No. 138. Irrigation in Field and Garden.
- No. 142. Principles of Nutrition and Nutritive Value of Food.
- No. 145. Carbon Bisulphid as an Insecticide.
- No. 155. How Insects Affect Health in Rural Districts.
- No. 157. The Propagation of Plants.
- No. 162. Experiment Station Work; Miscellaneous.
- No. 173. Primer of Forestry. Part I. The Forest.
- No. 175. Home Manufacture and Use of Unfermented Grape Juice.
- No. 181. Pruning.
- No. 182. Poultry as Food.
- No. 183. Meat on the Farm; Butchering, Curing, etc.
- No. 185. Beautifying the Home Grounds.
- No. 187. Drainage of Farm Land.
- No. 188. Weeds Used in Medicine.
- No. 192. Barnyard Manure.
- No. 196. Usefulness of the American Toad.
- No. 203. Canned Fruits, Preserves, and Jellies.
- No. 204. The Cultivation of Mushrooms.
- No. 222. Experiment Station Work; Miscellaneous.
- No. 228. Forest Planting and Farm Management.
- No. 243. Fungicides.
- No. 245. Renovation of Worn-out Soil.
- No. 249. Cereal Breakfast Foods.
- No. 255. The Home Vegetable Garden.
- No. 256. Preparation of Vegetables for the Table.
- No. 259. Experiment Station Work; Miscellaneous.
- No. 263. Practical Information in Irrigation.
- No. 266. Management of Soils to Conserve Moisture.

- No. 270. Modern Conveniences for the Farm Home.
- No. 277. The Use of Alcohol and Gasoline in Farm Engines.
- No. 278. Leguminous Crops for Green Manuring.
- No. 293. Use of Fruit as Food.
- No. 295. Potatoes and Other Root Crops as Food.
- No. 298. Food Value of Corn and Corn Products.
- No. 305. Experiment Station Work; Miscellaneous.
- No. 317. Experiment Station Work; Miscellaneous.
- No. 320. Experiment Station Work; Miscellaneous.
- No. 329. Experiment Station Work; Miscellaneous.
- No. 332. Nuts and their Uses as Food.
- No. 342. Experiment Station Work; Miscellaneous.
- No. 345. Some Common Disinfectants.
- No. 348. Bacteria in Milk.
- No. 358. A Primer of Forestry. Part II. Practical Forestry.
- No. 359. Canning Vegetables in the Home.
- No. 363. The Use of Milk as Food.
- No. 367. Lightning and Lightning Conductors.
- No. 371. Drainage of Irrigated Lands.
- No. 374. Experiment Station Work; Miscellaneous.
- No. 375. Care of Food in the Home.
- No. 377. Harmfulness of Headache Mixtures.
- No. 383. How to Destroy the English Sparrow.
- No. 389. Bread and Bread Making.
- No. 391. Economical Use of Meat in the Home.
- No. 393. Habit-forming Agents.
- No. 406. Soil Conservation.
- No. 408. School Exercises in Plant Production.
- No. 409. School Lessons in Corn.
- No. 410. Potato Culls as a Source of Industrial Alcohol.
- No. 413. The Care of Milk and its Use in the Home.
- No. 423. Forest Nurseries for Schools.
- No. 428. Testing Farm Seeds in the Home and in the Rural School.
- No. 429. Industrial Alcohol: Sources and Manufacture.

OFFICE OF EXPERIMENT STATION

- No. 101. The Selection and Installation of Machinery for Small Pumping Plants.
- No. 162. The Influence of Cooking upon the Nutritive Value of Meats.

BUREAU OF SOILS

Bulletin 73. Studies in Soil Oxidation.

BUREAU OF ANIMAL INDUSTRY

Bulletin 56. Facts Concerning the History, Commerce, and Manufacture of Butter.

Bulletin 131. Designs for Dairy Buildings.

Bulletin 158. Improved Methods for the Production of Market Milk by Ordinary Dairies.

REPRINTS FROM YEARBOOK

DEPARTMENT OF AGRICULTURE

1900. Amplification of Weather Forecasts.

1903. The Relation of Forests to Stream Flow.

1905. How to Grow Young Trees for Forest Planting.

1906. New Problems of the Weather.

1907. The Weather Bureau and the Public Schools.

1908. The Manufacture of Flavoring Extracts.

1908. Soil Mulches for Checking Evaporation.

1908. Plant Food Removed from Growing Plants by Rain and Dew.

1908. The So-called Change of Climate in the Semiarid West.

1908. The Wastes on the Farm.

1909. Comforts and Conveniences in Farmers' Homes.

FOREST SERVICE

Bulletin 36. The Woodman's Handbook.

Circular 114. Wood Distillation.

Circular 130. Forestry in the Public Schools.

Circular 139. A Primer of Wood Preservation.

WEATHER BUREAU

No. 235. Psychrometric Tables for Obtaining the Vapor Pressure, Relative Humidity, and Temperature of the Dew Point.

No. 285. Measurement of Precipitation.

Bulletin 311. Climate: Its Physical Basis and Controlling Factors.

No. 312. Invariability of our Winter Climate.

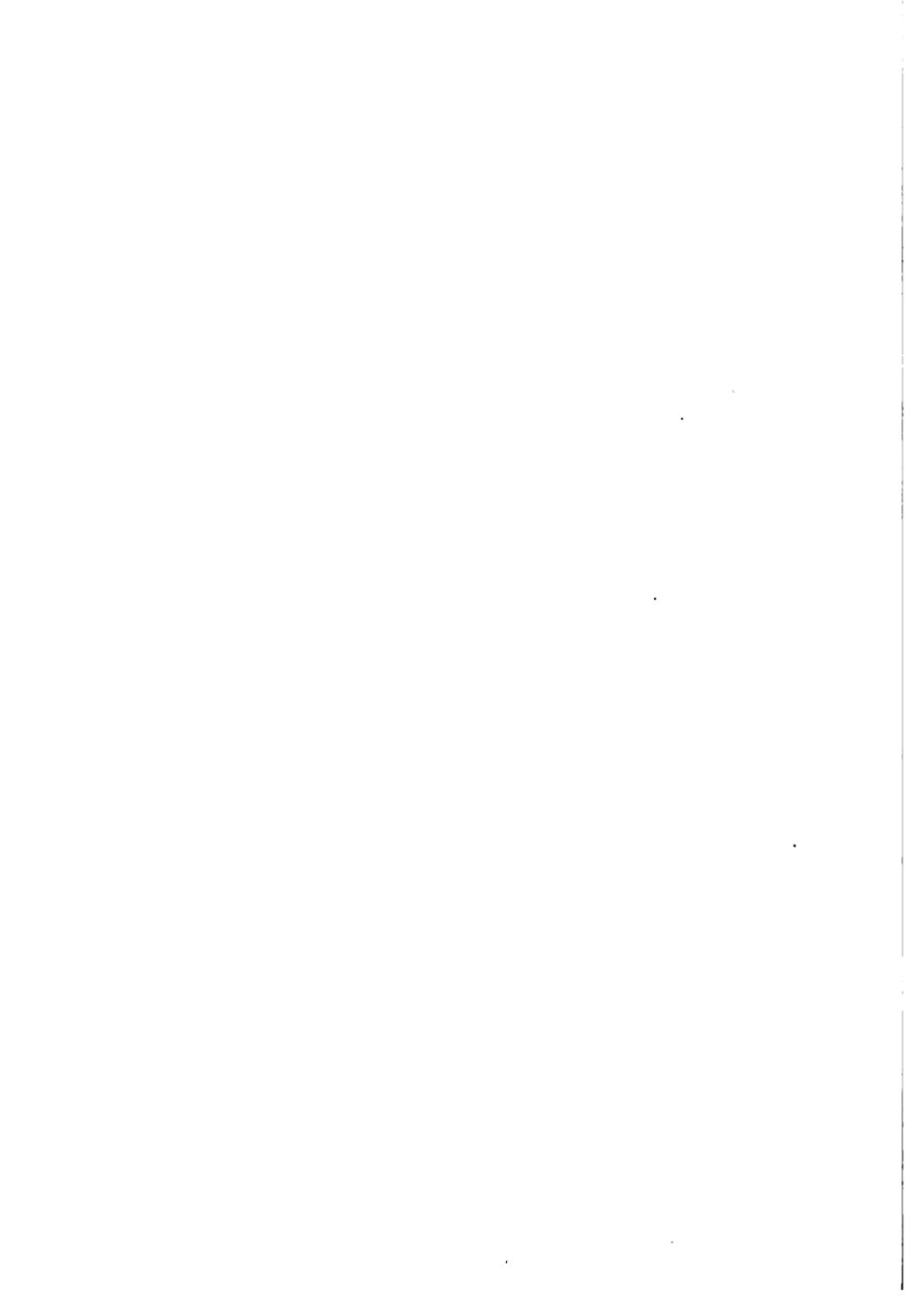
Explanation of the Weather Map.

Classification of Clouds. With Chart.

Photomicrographs of Snow Crystals.

BUREAU OF PLANT INDUSTRY

Circular 71. Legume Inoculation and the Litmus Reaction of Soils.



INTRODUCTION TO GENERAL SCIENCE

1. EXPLOSIONS

If we take a little gunpowder, or guncotton, and apply enough heat to make it "catch fire," the material will burn in a flash. If it is unconfined, it will burn quietly. On the other hand, if we confine it in a proper receptacle, such as a gun or cannon, and ignite it, there will be just as rapid combustion as in the first place. Since the material is confined, however, there will be a sudden overcoming of this restraint, producing what we call an explosion.

Take a little ether on a pellet of cotton, place it on a plate, and touch a burning match to it. The ether will burn rapidly, although quietly. Put more ether upon another pellet of cotton and place it in a wide-mouthed pint jar. Place a glass plate over the top of the jar and invert three or four times. Then cautiously slide the plate to one side and light the mixture of ether and air. An explosion is the result.

Take a brass tube six inches long and one inch in diameter. In one end place a tightly fitting cork stopper in which there are two copper wires, separated, but approaching each other to one sixteenth of an inch at that end of the stopper which is inside of the tube. Attach an induction coil, giving at least one quarter of an inch spark, to the other ends of the copper wires. Make a small swab of cotton on a short stick and swab out the "cannon," wetting the cotton with

naphtha, benzine, ether, alcohol, and gasoline, in turn. Each time, immediately after swabbing, close the open end of the cannon with another stopper, loosely fitted, and explode the mixture by means of electricity. The cork will be driven forcibly from the "cannon."

We conclude that if anything is burnt very rapidly in an inclosed space, an explosion will result. The conditions necessary for such a burning will be discussed in Section 4, Combustion.

References: —

1. 1703 : 16. Explosion of Hydrogen.
2. 1703 : 30. Deflagration the Explanation of Explosions.
 - a. 1704 : 196. Explosions in Mines.
 - b. 1708 : 111-112. Explosion.
 - c. 1709 : 30. Gas Explosion.
 - d. 1711 : 286-287. Mine Explosions.

2. COMPOSITION OF MATTER — DEFINITION OF HEAT

There are many facts which indicate that all matter is made up of small particles called molecules, and that these molecules are in constant motion. If they move fast, we say that the body is warm, and if we touch the body, we receive the sensation of heat. If we apply heat to a body, the molecules move faster; if by any means we make the molecules move faster, the body is warmer. If we hammer, rub, or in any way disturb the molecules, the body becomes hotter. We have merely to rub our hands together to realize this, and we are all familiar with the fact that a piece of lead, when hammered, becomes very hot. When these molecules move about, it is quite apparent that they need more room than if they had remained still; therefore nearly all bodies,

when heated, expand and occupy more space. See Section 15, Expansion Due to Heat. We make use of the expansion of mercury, in the thermometer, to indicate the degree of heat. See Section 16, Temperature and its Measurement.

References: —

1. 1703 : 127-128. The Molecular Theory.
2. 1803 : 82-83. Nature of Matter.
3. 1803 : 174-176.
 - a. 1801 : 253. Nature of Heat.
 - b. 1802 : 2-4. Matter.
 - c. 1804 : 247-248. Nature of Heat.
 - d. 1805 : 306-307. Heat and Energy.
 - e. 1806 : 299-300. Theory of Heat.
 - f. 1806 : 301. Relation of Heat and Temperature.
 - g. 1807 : 161-162. Theories of Heat.
 - h. 1808 : 206. Definition of Heat.
 - i. 1809 : 152-154. Nature and Production of Heat.

Experiments (for the teacher) in 1803 indicate the molecular constitution of solids, liquids, and gases.

3. STATES OF MATTER

All material exists in at least one of the following states: If the material has a shape which it can maintain, we call it a solid. If its shape is dependent upon the vessel in which it is held, we give the name liquid to it. Finally, if the material is neither solid nor liquid, but exists either in an invisible form or in a colored, vaporous condition, we call it a gas or a vapor. In a given kind of material the only difference between a solid and a liquid is that the liquid has more heat in it than the solid, and likewise the gas has more

heat in it than the liquid. For a given temperature matter exists in only one of these conditions, although a slight variation of temperature may cause it to change into another state. All matter existing in the sun is so hot as to be entirely composed of gas.

There is one material with which we are all familiar, that exists in the three states with a very slight change of temperature. Water, above thirty-two degrees F., and below two hundred and twelve degrees F., exists as a liquid; below thirty-two degrees F. it is a solid; above two hundred and twelve degrees F. it is a vapor. On account of the easy changing from one condition to another, water is a powerful agent in the transmission of energy. We shall see how the freezing of water can break rocks, on account of its expansion. Boiling water also exerts a tremendous pressure, and thus enables us to change heat into mechanical energy. In all of the explosions solids or liquids were changed into gases which occupied much more space than the solids or the liquids. If the space were occupied without resistance, there was a rapid, but quiet, burning; otherwise the space was occupied with force, and an explosion resulted.

References: —

1. 1304: 18-19. Air, Water, Rock.
2. 1703: 128. The Physical States of Matter.
3. 1803: 105-106. The Three States of Matter.
- a. 1201: 126-128. Gases, Liquids, and Solids.
- b. 1314: 6-7. The Three States of Matter.
- c. 1804: 127-129. The Peculiar Properties of the Three States of Matter.
- d. 1805: 101-105. States of Matter Explained.
- e. 1806: 347-349. Causes of Changes of State.
- f. 1806: 354-355. Causes of Changes of State.
- g. 1807: 3-5. The Three States of Matter.

4. COMBUSTION

We have seen that in explosions the burning took place rapidly, and throughout the whole mass at the same time. Explosions are, however, only one kind of chemical action which is called combustion. We are all familiar with the combustion which occurs in fireplaces, stoves, and lamps. This is called ordinary combustion, because we are familiar with it, but the most common sort of combustion is not generally recognized.

Before considering the kinds of combustion it might be well to understand what this phenomenon really is.

Experiment 1. — Ordinary Combustion.

Apparatus : Argand lamp chimney, cork stopper to fit bottom of chimney and one to fit top of chimney, wire nail about one inch long, small pan or saucer.

Materials : Piece of candle about two inches long, matches.

a. Cut notches on side of larger cork so that the amount removed is about one third of the cork, push nail through the center of the cork and stick the candle on it. Then light candle and let it burn in the open air.

Note waviness of the flame and the tendency to smoke.
Why is the flame wavy?

b. While the candle is burning, lower the Argand chimney over it, and push the chimney down over half the length of the cork.

Is the flame different now? Describe the difference. What makes the difference?

c. Push the chimney down over the whole of the cork, so that the bottom of the chimney rests on the table, and then put the other cork into the top of the chimney.

What happens? Why? Does it happen immediately? Why?

d. Remove top cork, remove candle, light it and return it to the chimney, pushing in bottom cork, halfway, as at first. Place bottom of chimney in a saucer nearly filled with water, and immediately insert top cork.

What happens? Why?

We conclude that combustion is concerned with two things,—the material to be burnt, called the *combustible*, and something which aids the combustion, called the *supporter of combustion*.

Returning now to the matter of combustion in general, we can state that it is the chemical union of at least two materials, the combustible and the supporter of combustion. Where this union is rapid, we have the ordinary combustion. When the combustible and supporter of combustion are thoroughly mixed, we have the proper conditions for an explosion. Yet the union is not always rapid; it may be very slow. The rusting of iron and the decay of wood are examples of slow combustion. The most common supporter of combustion is oxygen, which comprises about one fifth of the atmosphere. Whenever combustion takes place, whether it is ordinary or slow, heat is produced. In the case of many examples of slow combustion the heat escapes and cannot be perceived. Sometimes the heat does not escape, but accumulates gradually until the material is hot enough to produce ordinary combustion without the application of exterior heat. We call this *spontaneous combustion*.

Experiment 2. — Spontaneous Combustion.

Apparatus: Ring stand, or wire ring four inches in diameter, supported, test tubes, tweezers.

Materials: Phosphorus cut under water into pieces half the

size of a pea, and kept under water, carbon bisulphide, filter paper.

a. Pour 1 c.c. of carbon bisulphide into a test tube and drop in a piece of phosphorus which has been dried with a filter paper. Do not touch the phosphorus with the hands, or rub it. As soon as the phosphorus has dissolved, pour the solution on a clean piece of filter paper and place the paper on the ring. When the carbon bisulphide has evaporated, the phosphorus on the paper will burst into a flame.

b. Repeat (*a*), but place filter paper on a piece of iron—the flat base of the ring stand. What happens? Why?

Phosphorus combines very readily with the oxygen of the air. In the above experiment the phosphorus is spread over a large surface, so that the oxygen comes into contact with a considerable amount of it at one time. Thus a large quantity of heat is soon produced. The heat does not escape from the paper, since the latter rests on the ring, and is not in contact with anything else. Therefore the temperature of the paper rises, and ordinary combustion takes place. Oily rags, damp leaves or hay, and other material subject to slow decay may set fire to buildings through spontaneous combustion. Proper ventilation will aid in preventing danger.

References: —

1. 1703: 30-36. Combustion — Slow and Spontaneous.
2. Farmers' Bulletin No. 105: 26-27. Spontaneous Combustion of Hay.
 - a. 1701: 17-18. Combustion.
 - b. 1702: 49-50. Combustion.
 - c. 1704: 17. Definition of Combustion.
 - d. 1707: 37. Definition of Combustion.
 - e. 1708: 48-49. Combustion and Oxidation.
 - f. 1711: 51-57. Combustion in General.
 - g. 1713: 51-52. The Phlogiston Theory.

5. OXYGEN — ITS USES AND ACTION

Oxygen means acid-producing material, and it is found in nearly all the acids. Its use in the atmosphere, of which it composes about one fifth, is to support combustion. There can be no ordinary burning without the presence of oxygen. The oxygen combines with the carbon in the wood, coal, or other combustible, producing carbon dioxide, which passes off as a gas. It is the combination of the carbon and oxygen which produces the heat we obtain from our fires. Oxygen also causes the slow combustion which takes place in animals, producing animal heat, and burning up waste material absorbed by the blood. When water is thrown on the fire, it puts the fire out, simply because the water lowers the temperature of the burning substance and forms a film upon it which prevents the access of oxygen. Similarly, carbon dioxide bombs, which are exploded to extinguish fires, keep out oxygen, because the carbon dioxide is heavier than the oxygen and coats the surface of the combustible. See Section 90, The Chemical Engine.

Experiment 3. — Oxygen and Combustion.

Apparatus: Test tube 8" \times 1", stopper, with one hole to fit test tube, test-tube holder, or clamp, ring stand, glass tube 3" long, rubber tube 12" long, bread pan (pneumatic trough), four wide-mouthed, half-pint bottles, tweezers, deflagrating spoon, lamp, four glass plates 4" \times 4".

Materials: Powdered potassium chlorate, granulated manganese dioxide, wood splinters, charcoal in small pieces, powdered sulphur, iron picture cord, magnesium ribbon, phosphorus.

a. Mix equal parts of potassium chlorate and manganese

dioxide (about a tablespoonful in all) on a piece of paper, and then pour them into the test tube. Insert glass tube in cork, place in test tube, and hold test tube by ring stand obliquely. Place rubber tube over glass tube, and put other end of rubber tube under the mouth of a bottle which has been filled with water and inverted in the pneumatic trough, which should be half full of water. Heat the test tube slowly. A gas will soon come off and fill the bottle. This gas is oxygen. Collect four bottles of gas, and cover each, when full, with a glass plate.

b. Light a splinter of wood and then blow out the flame, obtaining a glowing coal on the splinter. Insert this in a bottle of oxygen. What happens?

c. Take a piece of picture cord 6" long, hold it with tweezers by one end, dip the other end in sulphur, and light the sulphur. When you get some burning sulphur on the wire cord, insert it in a second bottle of oxygen. Describe the results.

d. Burn a piece of magnesium ribbon partly in air, but mostly in oxygen. Conclusions?

e. Burn charcoal in air and in oxygen. Note that there is no flame.

The results of this experiment strengthen our conclusion in Experiment 1, that the act of combustion requires the presence of some substance from the air. We see that oxygen produces the same results as air, but much more vigorously, because it is not diluted with other gases which are present in the atmosphere. Where there is a sufficient supply of oxygen, there is complete combustion and no smoke. Smoke always indicates unburned fuel, and therefore means waste.

References: —

1. 1703 : 24-29. Oxygen: Its Preparation and Characteristics.
 - 1612 : 9-10. Oxygen in the Soils.
 - 1612 : 53-54. Properties of Oxygen.

- c. 1701: 13. Nature of Oxygen.
- d. 1701: 16-21. Properties of Oxygen and Combustion.
- e. 1702: 31-36. Oxygen — Preparation, Properties, and Importance.
- f. 1706: 11-18. Oxygen and its Relation to Life.
- g. 1707: 36-43. Oxygen and Combustion.
- h. 1709: 19-24. Oxygen and Combustion.

6. FUELS

The material which combines with oxygen in any combustion is called *fuel*. There are solid, liquid, and gaseous fuels, but all contain a common material — carbon.

The most universal fuel is wood. This is a compound made by growing plants, and consists chiefly of carbon and water combined.

The other solid fuels are the various kinds of coal, which will be considered in Section 137.

Liquid fuels are kerosene, gasoline, alcohol, naphtha, benzine, ether, turpentine, and other oils. They are all compounds of carbon.

Gaseous fuels are natural gas, artificial gas, and the vapors from several of the liquid fuels. All of the fuels will be studied in Section 137, Coal, and in Section 138, Petroleum, as well as in Section 28, Destructive Distillation.

References: —

- 1. 1702: 115-116. Fuels.
- 2. 1710: 23-32. Fuels.
 - a. 1701: 399-400. Petroleum Products.
 - b. 1704: 203-205. Fuels from Petroleum.

7. BLASTING

If a hole in a ledge of rock, or the stump of a tree, is filled with gunpowder or dynamite packed down with sand, ignition of the powder will cause an explosion and considerable local damage. The solid powder turns instantly to gases, which, due to their nature and the high temperature, occupy an enormous volume compared with the solid from which they came. This sudden expansion causes the breaking and rending of the surrounding material.

The question which very naturally arises is: Why does the powder burn when there is apparently no air, or oxygen, present? We have learned that oxygen must be present in other cases of combustion, and this example is no exception. The chemicals of which the powder is made contain the oxygen in just the right proportion to produce complete combustion, and it is so thoroughly blended that the combustion takes place throughout the whole mass at the same time. This kind of combustion is called *deflagration*. The smoke of powder is not carbon, but is due to the formation of a small amount of solid matter. Where no solid matter is formed, we have smokeless powder.

References: —

1. 1703:30. Deflagration.
- a. 1704:307-308. Gunpowder.
- b. 1705:180. Nitroglycerine and Guncotton.
- c. 1707:331-333. Gunpowder.

Also see references under Section 1.

8. GAS AND GASOLINE ENGINES

Blasting is only one of the uses we make of explosions. If the explosions are limited, or controlled, and one part of the

container is free to move, we can change the force of the explosion into rotary motion, as in the gas engine. Here a mixture of gas and air, in the right proportions for complete combustion, is drawn into a cylinder by the forward stroke of the piston, compressed by the return stroke, and finally exploded, thus pushing the piston forward with great energy. It is then forced out upon the return of the piston. This is the so-called four-cycle gas engine.

In the two-cycle engine the back stroke of the piston causes a partial vacuum in the crank case, which is inclosed, and a mixture of gas and air is drawn in. The forward stroke of the piston forces this mixture up into the cylinder, the fresh mixture pushing out the burnt gases and being compressed at the return of the piston. The explosion then takes place and forces the piston forward. The incoming fresh mixture forces out the old burnt mixture.

References: —

1. 1803: 191-194. The Principle of the Gas Engine.
2. Farmers' Bulletin No. 277: The Use of Alcohol and Gasoline in Farm Engines.
 - a. 1607: 522-530. Gasoline Engines.
 - b. 1801: 299-300. The Gas Engine.
 - c. 1802: 322. The Gas Engine.
 - d. 1809: 208-210. International Combustion, or Gas Engines.
 - e. 1810: 193-196. The Gas Engine.

9. ANIMAL HEAT

We call the heat produced by slow combustion of food within the body, animal heat. This combustion, while slow, is perfect. All of the carbon in food is completely combined with oxygen, and its combustion causes no smoke. Combustion likewise takes place within the lungs, and moreover,

the red corpuscles of the blood absorb the oxygen, which we inhale, and carry it to all parts of the body, to burn up waste material. Thus it is that all parts of the body are warm. If, however, the circulation is poor, so that this destruction of waste is not complete, we have cold feet, cold hands, and, in very severe cases of poor circulation, bad chills.

The temperature of most animals is ninety-eight and four tenths degrees F. No matter what the weather may be, the temperature of a healthy person does not vary more than one half of a degree. A variation, upward or downward, of a few degrees from the normal temperature will result in death. Thus it is that fevers and chills are weakening to the constitution, and, unless properly taken care of, may be fatal.

If we become cold, we may exercise and increase the circulation, thereby increasing the combustion throughout the whole body, and maintaining the temperature which would otherwise be lowered. Or, if we desire, we put on heavier clothes, which serve to keep in the heat of the body. If we become warm, we remove some of our clothing.

In Section 89, Carbon Dioxide, this matter will be considered further.

References: —

1. 1503: 348-349. Blood Temperature.
2. 1503: 398. The Bodily Heat as Affected by Alcohol.
3. 1703: 11-12. The Kipp Generator.
- a. 1506: 32-33. Oxidation in the Body.
- b. 1507: 48-49. Amount of Animal Heat.
- c. 1507: 240. Loss of Heat from the Body.
- d. 1509: 211-212. Heat of the Body.
- e. 1511: 98-99. Animal Heat.

Experiment 4. — Complete and Incomplete Combustion.

Apparatus: Alcohol lamp having a collar around the wick

one inch high with an inlet tube one fourth of an inch in diameter, a one pint Kipp generator, rubber tubing.

Materials: Turpentine, sodium peroxide in cubes.

a. Fill alcohol lamp with turpentine, put collar around wick and connect with the oxygen generator. Light the wick before the oxygen is turned on, and notice the kind of flame which is produced. Then gradually turn on the oxygen and note the change which takes place in the flame. What is smoke? Why is it formed?

Sodium peroxide, when combining with water, forms sodium hydroxide or caustic soda, and sets free oxygen. To use the Kipp generator, place a few pieces of sodium peroxide in the middle bulb, put the parts together, and pour in enough water to fill the lower bulb and about half of the middle bulb. When the outlet is closed, the gas which is being generated pushes the water away from the sodium peroxide, and thus the action is stopped automatically.

10. FLAMES

All combustion is not accompanied by flames. Slow combustion of any kind, whether in chemicals, in decaying matter, or in the production of animal heat, does not produce flame. It is only where the temperature is high enough to change the solid or liquid fuel into gas that flames are produced. A flame, then, is gas in combustion.

In Section 28, Destructive Distillation, we shall see that when any solid or liquid combustible is heated, part of its material is changed into gas. The experiments will show this fact in relation to a candle flame.

1. 1703: 35-36. Flames.
2. 1703: 214-219. Structure of Flames.

- a. 1701: 211-217. Flames.
- b. 1704: 184-187. Luminous and Nonluminous Flames.
- c. 1705: 54-56. Experiments with Flames.
- d. 1707: 204-208. Flames — The Safety Lamp.
- e. 1708: 107-109. Flames.
- f. 1709: 238-241. Candle and Gas Flames.
- g. 1712: 319-321. Flame.

Experiment 5. — Source of Flames.

Apparatus: Piece of glass tubing 6 inches long.

Materials: Candle, matches.

a. Light candle and allow it to burn for a minute. Then light a match, and, blowing out the candle flame, immediately hold the burning match over the candlewick a distance of about half an inch. What happens? Explain.

b. After candle has been burning for over a minute, insert one end of the glass tube into the candle flame, at a very slight angle from the vertical. Apply lighted match to the other end of tube. What burns? Where did the material come from?

11. FIRST AID TO THE BURNT

Immediate action is what counts. Where the clothing is on fire, the flames should be slapped out, or, if a large amount of the clothing is burning, the person should be wrapped in a mat or rug, and rolled on the floor. A coat may be used in place of the rug. Always keep the head lower than the rest of the body to avoid inhalation of flames.

When burns are not severe, ordinary baking soda may be applied after the burn has been wet with warm water, to make the powder stick. Bandage with a clean cloth which has been torn into strips three fourths of an inch wide.

If the burns are serious, the following method may be used:

Prick with a sterilized needle any water blisters, then apply equal parts of limewater and olive oil. Cover burn with absorbent cotton which has been soaked in the same mixture, and over this place dry cotton. Then bandage. Limewater may be prepared by putting one ounce of fresh unslaked lime into a pint of water, shaking, and allowing to settle. If lime-water is not at hand, use baking soda and olive oil.

White lead, mixed into a thick paste with linseed oil, may also be used. Apply with a soft brush. Any of the following materials may be applied, but as quickness means much to the patient, ease in obtaining the remedy should have first consideration: baking soda, olive oil, limewater, white lead and linseed oil, powdered chalk, starch (either from potatoes or corn), flour of any kind, and mucilage or dissolved gelatine covered with any of the powders mentioned above.

References :—

1. 1503 : 398. Cuts, Bruises, and Burns.
 - a. 1505 : 24. Treatment of Burns.
 - b. 1506 : 298. Burns and Scalds.
 - c. 1507 : 248. Burns.
 - d. 1508 : 327. Burns.
 - e. 1511 : 375. Burns and Scalds.

12. STERILIZATION BY HEAT

When we break the skin in any way, the protective covering is removed and our bodies are open to the attacks of small plants called *bacteria*. Bacteria produce more trouble in a wound which has not been properly taken care of than the injury itself. Sometimes we are obliged to inflict wounds upon ourselves, and with a little care we can guard against admitting bacteria unnecessarily.

If we desire to remove a splinter, or open a pimple, or larger

accumulation of pus, we should be careful that the knife, or needle, has no bacteria on it. The needle may be heated red-hot and used as soon as cool, with perfect safety. The same treatment would ruin a knife, however, and the latter should be boiled for twenty minutes to secure absolute sterilization, although two or three minutes will be long enough in most cases. Sterilization may be thought of as the removal of undesirable bacteria. Thus cooking food protects us, as there may be harmful bacteria present which will be killed by the heat.

References: —

1. 1710 : 113. Effect of Steam upon Germs.
2. 1901 : 110-112. Death Temperature of Bacteria.
3. 1901 : 191-196. Pasteurization.
 - a. 1505 : 162-164. Protection against Disease Germs.
 - b. 1507 : 73. Sterilization and Disinfection.
 - c. 1508 : 80. Pasteurization.
 - d. 1902 : 171-176. Sterilization and Pasteurization.

13. ANTISEPTIC WASHES — DISINFECTANTS

We know that when we have a cut or bruise, bacteria of disintegration and disease may enter and attack it. In this event a large scab is formed, and often the place becomes a running sore. We know that this scab and the oozing material are composed wholly of dead white corpuscles, which have lost their lives fighting with bacteria. On the other hand, if we treat a cut or bruise with some antiseptic, which tends to kill all harmful bacteria, the wound will get well without any large scab, and without any oozing of pus. Perhaps the best agent we can use for this purpose, and the handiest, is corrosive sublimate. It comes in tablets, of such a size that the solution of one tablet in a

pint of water gives the right strength for disinfecting purposes. If a cut is bathed immediately with this solution, it will get well in a wonderfully short time.

It is well to recognize the fact that there are harmful bacteria and to guard ourselves against them. Nevertheless, we should not live in constant fear of them. The best way to escape the attacks of bacteria is to maintain our bodies in a healthful condition. To do this, we should have a proper amount of sleep, eat a sufficient quantity of healthful food, exercise, and avoid excesses of any kind.

In order to have healthful food and live in healthful houses, disinfectants should be used whenever our sense of smell notifies us that there is decay around us. On the other hand, there may be times when it becomes necessary to use disinfectants, even if there is no unpleasant odor. To clean a building or a sick room thoroughly, several disinfectants may be used. Chloride of lime and carbolic acid are favorites with many, chiefly because they have a "clean" smell. They are not nearly as effective as the burning of sulphur or the use of formaldehyde, or potassium permanganate and formaldehyde together.

References: —

1. 1503 : 171-172. Prevention of Bacterial Diseases.
2. 1710 : 108-116. Disinfectants, etc.
3. 1901 : 255-261. Disinfectants.
 - a. 1506 : 274-278. Disinfection.
 - b. 1509 : 290-292. Disinfection.
 - c. 1511 : 376-379. Disinfectants and How to Use Them.
 - d. 1902 : 323-326. Disinfectants and their Application.
 - e. 1904 : 158-163. Disinfection and Disinfectants.
4. Farmers' Bulletin No. 345. Some Common Disinfectants.

14. CHEMICAL EFFECTS OF HEAT

When the various combustibles united with oxygen and burned quietly, or exploded, we had examples of chemical action. We learned that heat starts chemical action. After the action begins, it gives off heat. In Section 31 we shall study chemical action as a source of heat.

If we remember that heat is the motion of molecules, and that they not only move, but strike against their neighbors, we can see that this motion, if increased, would make them strike harder, and even unite with some other dissimilar molecules. Thus it is that heat aids chemical action.

Heat produces several very complex changes in meat and other substances which have had life, and these changes make the substances more suitable for food. Heat also causes chemical changes in food which are very similar to the processes of digestion. Thus boiling starch slowly changes it into a sugar. See Section 29, Cooking.

References: —

1. 1703 : 24. Heat Liberates Gases from Compounds.
2. 1703 : 428. Effect of Heat on Starch.
3. 1901 : 36. Heat Aids Plant Growth.
 - a. 1507 : 53-55. Effects of Heat on Food.
 - b. 1708 : 35. Combination Caused by Heat.
 - c. 1709 : 2-3. Effect of Heating a Metal in Air.
 - d. 1711 : 24-27. Physical and Chemical Effects of Heat.

15. EXPANSION DUE TO HEAT

The first effect of heat on a body is to cause its molecules to move faster. Since these hit against their neighbors, and are in turn hit by them, the body as a whole becomes larger, and we say that expansion has taken place. The only ma-

terial which does not expand, when heated, is rubber; this contracts.

While we generally notice the expansion of a body in one direction only, that is, linear expansion, it must not be forgotten that a body expands in three dimensions. If we know the linear expansion of a body, however, we can easily calculate the cubical expansion, as the increase for the same change in temperature is always proportional to the length.

Not only do solids expand, but the same is true of liquids and gases. The expansion of liquids and gases gives rise to many phenomena which will be described in other sections.

References: —

1. 1803 : 89. Expansion of Liquids.
2. 1803 : 104. Expansion of Solids.
3. 1803 : 144. Unequal Expansion of Solids.
 - a. 1801 : 261-263. Expansion of Solids, Liquids, and Gases.
 - b. 1802 : 294-298. Expansion Due to Heat.
 - c. 1804 : 265-270. Effects of Heat Expansion.
 - d. 1805 : 297-302. Expansion and its Applications.
 - e. 1806 : 322-324. Applications of Expansion.
 - f. 1807 : 177-178. Effects and Applications of Expansion.

Experiment 6. — Expansion Due to Heat.

Apparatus: Glass bulb tube, flask 100 c.c., two-hole rubber stopper, thermometer, glass tube 3 feet long, ring stand, asbestos mat 5" \times 5", lamp, two iron screw eyes, one of which will just pass through the other, two pieces of wood for handles.

a. Put bulb tube through one hole of stopper and insert in flask, half filled with water; place hand on bulb. What happens? Warm bulb very gently with lamp. What happens? Let bulb cool, and explain what takes place.

b. Place the thermometer in one of the holes of the stopper and the glass tube in the other. Fill the flask full of water

and insert the stopper. This will cause the water to run up the tube a short distance. Place flask over the asbestos mat, on ring stand, and heat slowly. Should you say that expansion is proportional to the change in temperature?

c. Screw each screw eye into a piece of wood to serve as handles. Heat the smaller screw eye, and then see if it will pass through the larger screw eye. State two methods which may be employed to enable you to accomplish this. Tell what would be the result if you had placed the larger screw eye in some freezing mixture instead of heating the smaller screw eye.

16. TEMPERATURE AND ITS MEASUREMENT

In considering heat, we learned that it was due to the motions of the molecules of a body. If one body is giving heat to another body, we say that the intensity of heat of the first body is greater than that of the second body. This intensity of heat is called temperature, and, as has been stated, temperature is usually measured by the expansion of some material. Mercury is the material used for ordinary temperatures, as its expansion is almost proportional to change in temperature, but colored alcohol is used for temperatures which are very low, while in extreme cases the gas thermometer is used.

There are two scales of temperature, the "Fahrenheit," and the "Centigrade" or "Celsius." In the Fahrenheit scale, thirty-two degrees is arbitrarily taken as the freezing point of water, and two hundred and twelve degrees as the boiling point of water. Zero is merely thirty-two degrees below the freezing point. In the Centigrade thermometer, zero is taken as the freezing point, and one hundred degrees

as the boiling point, of water. It has this advantage, however, that zero means a definite thing (namely, the freezing point), and that one hundred is an easier number with which to deal than two hundred and twelve. In foreign countries, and in scientific work everywhere, the Centigrade scale is used, and no doubt it will gradually supplant the Fahrenheit, even for common purposes.

References: —

1. 1803 : 129-134. Thermometry.
- a. 1801 : 254. Temperature.
- b. 1801 : 255-258. Thermometers and Thermometer Scales.
- c. 1804 : 251-252. Definition of Temperature.
- d. 1804 : 254-257. Graduation of Thermometers.
- e. 1805 : 292-296. Temperature and Thermometers.
- f. 1806 : 310-313. Temperature and Thermometers.
- g. 1807 : 163. Temperature Defined.
- h. 1808 : 206-207. Temperature Defined.

Experiment 7. — The Fixed Points of the Thermometer.

Apparatus: A thermometer with scale — 10° to 225° Fahrenheit, a Centigrade thermometer with scale — 20° to 110°, two beakers 100 c.c., ring stand, asbestos mat, 5" × 5", lamp for heating.

Materials: Crushed ice, water, matches.

a. Put both thermometers in the beaker which contains the ice, and allow them to remain until the mercury ceases to fall. What do the thermometers indicate? What is the difference between 0° C. and 32° F.?

b. Put both thermometers in some cool water and heat the beaker over an asbestos mat. Read the thermometers when boiling begins. Which is *hotter*, the Fahrenheit thermometer or the Centigrade thermometer?

17. CONDUCTION

Heat is conveyed from one body to another, or from one part of the same body to another part, by means of the molecules jostling against one another. If we heat one end of a piece of copper wire, the other end soon becomes hot, because the more rapidly moving molecules hit against their neighbors. Not only do solids conduct heat, but liquids and gases may convey heat in this method, although not as readily. Materials which conduct heat are called *conductors*. There are good conductors and poor conductors.

This explains why metals and stone feel colder than wood or cloth on a cold day, and warmer on a hot day, although all of the objects are at the same temperature. In the presence of cold, therefore, good conductors will feel cold in comparison to some given body, and will take away its heat more readily than will poor conductors. Similarly, in the presence of heat, they will feel warmer than the body, and give up their heat to it readily.

References: —

1. 1803: 216-219. Conduction.
- a. 1801: 286-288. Conduction and Applications of Conduction.
- b. 1804: 294-296. Conduction.
- c. 1805: 322-325. Conduction.
- d. 1806: 301-305. Conduction.
- e. 1807: 164-166. Conduction.
- f. 1808: 216-217. Conduction.

Experiment 8. — Conduction.

Apparatus: Burner, glass tube 6" long, copper and iron wires No. 12, 6" long, test tube 6" \times $\frac{3}{4}$ ", test-tube holder.

- a. Hold one end each of the glass tube and of the copper

and iron wires in the flame. Which one conducts the heat to the hand first? Which one last?

b. Fill the test tube nearly full of water and place it in the test-tube holder. Hold the tube obliquely so that the flame of the burner heats the top of the water, but does not touch the glass where there is no water. When the water boils at the top, feel the bottom of the tube. Is water a good conductor of heat?

18. CONVECTION

All bodies expand when heated, whether they are solids, liquids, or gases. It follows that a given weight of material occupies more space, when heated, than when cold. Therefore a given volume of a hot material weighs less than the same volume of the same material when cold. Thus, if there is a mixture of hot air and cold air, or hot water and cold water, the colder, heavier material will push up the warmer, lighter material. We say that hot air rises; it is more correct to say that it is pushed up by colder air. For the same reason a balloon does not rise of itself, but is pushed up by the air, which is heavier than the contents of the balloon.

In the above-mentioned method of heat distribution, the material heated keeps turning over and over. Thus it is called *convection*, and the currents, which are produced, are called *convective currents*. Upon convection are based methods of hot-air heating, and hot-water heating of houses, ventilation, and domestic hot-water boilers. These are described in the next section. The winds, which are caused by convective currents on an enormous scale, are treated in Section 04, Winds.

References:

- 1803: 210-221. Convection of Liquids.
- 1801: 288-290. Convection in Water.

- b. 1802 : 286. Convection.
- c. 1804 : 296-298. Convection.
- d. 1805 : 325-326. Convection.
- e. 1806 : 305-306. Convection.
- f. 1807 : 166-167. Convection.
- g. 1808 : 217. Convection in Gases.
- h. 1809 : 160. Convection.

Experiment 9. — Convection in Gases.

Apparatus: Chalk box and cover, piece of window glass to fit as a sliding cover in chalk box.

Materials: Candle not over 2" long, matches, touch paper.*

a. Cut a hole one inch square in one side of the box close to one end and another hole in the same side of the box, but close to the other end. Opposite this latter hole cut a third, in the other side of the box. Place the box on the table with the end having two holes near it at the top. Light a candle and place it near the bottom hole. Take the wooden cover of the box and make a partition of it, dividing the box lengthwise into two equal parts. In this partition, cut a hole near the bottom. Slide the glass cover in place and apply smoking touch paper near the lower hole. Where does the smoke go? Why?

b. Close lower hole and place touch-paper near upper hole of other side. Describe and explain.

Experiment 10. — Convection in Water.

Apparatus: Test tube, test-tube holder, lamp.

Materials: Sawdust.

a. Fill a test tube nearly full of water and mix in it a very small pinch of fine sawdust. Hold the test tube vertically

* To make touch-paper: Soak blotting paper in a water solution of potassium nitrate (saltpeter) containing all of the potassium nitrate which will dissolve. Dry and cut into strips $\frac{1}{2}$ inch long.

over the flame and to one side of it so that the flame will heat one side of the water only. Tell what you see, and explain. Why is sawdust added to the water?

19. VENTILATION AND HEATING OF BUILDINGS

Nearly every application of knowledge which we make use of in business or for our comfort is founded upon some of the various phenomena of nature. In the last experiments we saw how easy it is to produce currents of air and water by means of heat, while at the same time the heat was distributed. We make use of these facts in the ventilation and heating of buildings.

The Hot-air System. Coal or wood is burned in a fire pot which is surrounded by an air space. This space has one inlet for cold and fresh outdoor air, and several outlets, each of which leads to some room of the house. The air around the fire pot becomes hot, and therefore expands, and is lighter per given volume. This is pushed out of the heating space by the outside cold and heavier air coming in. Thus the rooms of the house are supplied with a continuous stream of warm, fresh air. This system ventilates as well as warms the whole building. Its great disadvantage is that the windy side of the building does not receive its share of the heat. In order to overcome this fault, power-driven fans are placed near the furnace, and the warm air is forced to go where it is required.

The Hot-water System. In this system the fire box is partly made of coils of iron pipes which contain water. The ambition of the builder is to have all of the heat of the fire given to the water. The water, when warm, expands, is lighter than the colder water, and circulates around the pipe system of the whole house. The rooms are supplied with coils of pipes,

called *radiators*, which are intended to give large surface so that the heat of the water may be readily given up to the air of the room. It will be noted that no fresh air is supplied by this method of heating, and therefore some ventilation is necessary. The advantage of this system is that all of the house may be evenly heated whether the wind blows or not. See Section 190, Dangers of Vitiated Air.

Heating by means of steam will be explained in Section 25, Evaporation and Condensation.

References: —

1. 1710 : 33-45. Heating and Ventilation.
2. 1803 : 223-225. Heating and Ventilation.
 - a. 1801 : 290. Ventilation.
 - b. 1804 : 298-302. Ventilation.
 - c. 1805 : 326. Ventilation.
 - d. 1808 : 218. Ventilation.
 - e. 1809 : 161. Ventilation.

20. RADIATION OF HEAT

Heat is also radiated; that is, it passes off in straight lines from one body to all other bodies. In some way the swiftly moving molecules have the power to give out energy very similar to, though much weaker than, the energy we receive from the sun. Radiated heat is very noticeable if we are in front of an open fireplace, for the radiation there is caused only from the action of molecules. The energy from the sun may be condensed by means of a lens or "burning glass" and so high a temperature obtained as to set fire to paper, cloth, and even wood and coal.

Material which is black and rough is the best radiator; that which is smooth and shiny makes a very poor radiator,—therefore if we wish to keep anything hot, we should place it

in a very smooth, highly polished dish. Thus coffee, in a brightly polished pot, keeps warm longer than in a darker, rougher dish.

References: —

1. 1002 : 390. The Energy Radiated by the Sun.
2. 1803 : 221-222. Nature of Radiation.
- a. 1001 : 153-154. Solar Radiation.
- b. 1004 : 166. Radiation from the Sun's Surface.
- c. 1801 : 291-292. Radiation of Heat.
- d. 1802 : 286-288. Radiation.
- e. 1804 : 303. Radiation.
- f. 1804 : 416-421. Thermal Effects of Radiation.
- g. 1805 : 327-328. Radiation of Heat.
- h. 1806 : 306-307. Radiation.
- i. 1807 : 167-170. Radiation of Heat.
- j. 1808 : 218-221. Radiation of Heat.

Experiment 11. — Radiation of Heat.

Apparatus: Two baking powder or spice cans, with labels removed, thermometer, alcohol lamp filled with turpentine (one for the class is enough).

a. Polish the outside of one can, and smoke the outside of the other can. Fill both with boiling water and place them in the shade and out of a draft. At the end often minutes take the temperature of each. State results and explain. Repeat at the end of ten minutes more.

21. ABSORPTION OF HEAT

The only kind of heat which is said to be absorbed is *radiant heat*, or the heat of radiation. Absorption of this radiant heat is not very noticeable except in the case of heat which is received from the sun. A good radiator is a good absorber. Thus black and rough clothing is warmer than white, if the

person is to be in the sunshine. For the same reason, dark-colored earth absorbs more heat than the lighter-colored soil, which may be desirable when heat is needed for crops.

If materials were transparent, they would not absorb any heat. There is, however, no substance that is truly transparent, and so there is always some absorption. The atmosphere absorbs about forty per cent of the sun's heat which reaches it, and dirty water absorbs practically all of the heat within a few inches of its surface. If we sit by a window, in the sunshine, we may be warmed by the energy from the sun, although the window glass, through which the energy passes, is not noticeably heated. Therefore radiant "heat" is really not heat, but a form of energy which may be changed into heat.

An application of absorption of heat is the solar heater for water. This consists of a large number of pipes arranged in a glass-covered box, which is usually placed upon the roof of the house. The water must pass through all of the pipes before it can reach the outlet. The interior of the box and also the pipes are painted black, without any gloss, and the water absorbs enough heat to be sufficiently warm for washing dishes and for other domestic purposes. Why is the box covered with glass?

References: —

1. 1103 : 27-28. Absorption of Heat by the Atmosphere.
2. 1803 : 464-465. Radiation and Absorption.
 - a. 1801 : 292-295. Absorption — Selective Absorption.
 - b. 1802 : 324. Effect of Absorption.
 - c. 1804 : 422. Good Radiators, Good Absorbers.
 - d. 1805 : 328-331. Absorption — Selective Absorption.
 - e. 1806 : 392. Absorbing Power.
 - f. 1807 : 170-172. Reflection and Absorption at Surfaces.
 - g. 1808 : 221-223. Radiating and Absorbing Powers.
 - h. 1810 : 177. Absorption of Radiant Energy.

Experiment 12. — Absorption of Heat.

Apparatus: The same as in Experiment 11.

a. Put equal amounts of water of the same temperature into the two cans, and expose them to the sunlight, in a place which is sheltered from wind. Leave for twenty minutes and then test the temperature of each. Which is warmer? Did you expect this? Nearly all of the "laws" of nature work both ways.

Experiment for places where there is snow: Place squares of different-colored cloth, including white and black, on the surface of the snow, in the sunshine. Some will absorb more heat than others, and will sink deeper into the snow. Measure the different depths, and arrange the colors in a table, according to the amount of heat which they have absorbed in a given time.

22. MEASUREMENT OF HEAT

Section 16 treated of the measurement of temperature, but was not concerned with the measurement of heat. We have learned that heat is due to the motion of the molecules. Now the temperature of a body indicates the average velocity of the molecules, while the quantity of heat is due to the sum total of all of the molecular motion.

The unit of heat measurement is the *calorie*, and it is the amount of heat which is necessary to raise the temperature of one gram of water from 4° to 5° Centigrade. (One ounce is equivalent to about twenty-eight grams.) This is the unit which is used in all scientific work, but there is another unit which is used in engineering. This is called the British Thermal Unit, and it is the amount of heat which is necessary to raise one pound of water one degree Fahrenheit.

A large amount of water, at a moderate temperature, may contain more heat than a smaller amount of water at a higher temperature.

References: —

1. 1803 : 175. Unit of Heat — The Calorie.
- a. 1801 : 269-270. Measurement of Heat.
- b. 1802 : 272. Measurement of Heat.
- c. 1804 : 260-261. Thermal Units.
- d. 1805 : 316. Measurement of Heat.
- e. 1806 : 341. Measure of Heat.
- f. 1807 : 182. The Heat Unit.
- g. 1808 : 237. The Measurement of Heat.
- h. 1809 : 179. The Unit of Heat — The Calorie.

Experiment 13. — Quantity of Heat Comparison.

Apparatus: Burner, ring stand, asbestos mat, beakers, 100 c.c., 150 c.c., 200 c.c., thermometer.

a. Boil some water in the 150 c.c. beaker and have 50 c.c. of water in the 100 c.c. beaker, and 150 c.c. of water in the 200 c.c. beaker, both of the same temperature. Completely fill these two beakers with boiling water, thus adding 50 c.c. to 50 c.c., and 50 c.c. to 150 c.c. Take the temperature of each, after stirring. Which has the higher temperature? What is the relative amount of change in degrees?

b. Since the same amount of heat was added in each case, draw your conclusions in regard to the relation between heat and temperature.

23. HEAT OF CHANGE OF STATE

There is another rather peculiar change, caused by heat, which is called *change of state*. By this is meant the passing from the solid to the liquid form, and from the liquid to the gaseous. A liquid contains more heat energy than does the

same material in a solid state, while a gas contains still more heat energy than does the same weight of liquid. The temperature of ice cannot be raised above 32° Fahrenheit until all the ice is melted. The heat goes to give the molecules enough energy to exist in the form of a liquid. For a similar reason water cannot be heated in the open air, above its boiling point — 212° Fahrenheit. The heat gives the water molecules sufficient energy to exist in the gaseous form. Now, since there is no loss in nature, this same amount of heat which is necessary to change a solid into a liquid is given out again, when the liquid changes back into a solid. Farmers in cold countries make use of this fact by placing in their cellars large tubs of water, which, as it freezes, gives out to the cellars the same amount of heat that would be necessary to melt the same weight of ice to water. Thus vegetables may be kept from freezing, since their freezing point is slightly lower than that of water. Again, the heat which is necessary to change water into steam is given out when the steam condenses to water again. Upon this is based the system of steam heating. The water which leaves the steam radiator has just as high a temperature as the steam from which it was condensed, although a great amount of heat has been given off by the condensation of the steam. See Section 25, Applications of Evaporation and Condensation.

References: —

1. 1803 : 196. Definition of Heat of Fusion.
2. 1803 : 198. Latent Heat of Fusion.
3. 1803 : 203. Definition of Heat of Vaporization.
4. 1803 : 204. Latent Heat of Vaporization.
 - a. 1801 : 274-278. Heat and the Change of State.
 - b. 1802 : 304. Solidification.
 - c. 1804 : 278-287. Fusion and Vaporization.
 - d. 1805 : 333. Heat of Fusion.

- e. 1805 : 339-341. Heat of Vaporization.
- f. 1806 : 350. Heat of Fusion.
- g. 1807 : 189-190. Heat of Fusion.
- h. 1807 : 204-205. Heat of Vaporization.
- i. 1808 : 239-240. Latent Heat of Fusion and of Vaporization.
- j. 1809 : 184-185. Heat of Fusion.
- k. 1809 : 194. Heat of Vaporization.

Experiment 14. — Heat of Vaporization and of Fusion.

Apparatus: Burner, ring stand, asbestos mat, 3" evaporating dish, thermometer.

Materials: Ice.

a. Put about 5 c.c., of ice water in the evaporating dish and see how many minutes it takes to bring it just to a boil. Then, keeping the burner in the same position and condition, see how many minutes it takes to boil away the water. How many calories did it take to raise the temperature of 5 c.c. (=5 grams) of water from 0° Centigrade to 100° Centigrade? Since the amount of heat which is received from a burner is nearly constant, about how many calories did it take to boil away the liquid; that is, how much did it take to change 5 c.c. of water at 100° C. into steam at 100° C.? Then how much did it take for one gram of water?

b. Put 5 g. of ice in the evaporating dish, place it on the mat, over the burner, and see how many minutes elapse before it is melted. Then continue to heat the water for the same number of minutes. At the end of this time note the temperature of the water. How many calories of heat were required to change 5 g. of water from 0° C. to the final temperature? Then how many calories for 1 g. of water? Since the heat which was received from the burner may be considered as being constant, how many calories were needed to melt 1 g. of ice? Compare your results with any of the reference books.

24. EVAPORATION REQUIRES HEAT

We saw in Experiment 14 that heat is required to change a liquid into a gas, at least in the case of boiling. Yet water evaporates, or changes from the liquid form to the vapor form, at all temperatures. For instance, the clothes dry on the line, on wash day, although the temperature of the air is far below the boiling point. It can be shown that even ice may evaporate without first melting, that is, ice may change from the solid state directly into the vapor state and not pass through the liquid state.

Although it is not always evident, yet every molecule of a liquid which leaves the liquid and becomes part of a gas or vapor requires heat in order to make the change. This heat comes from the liquid, which receives its heat from its surroundings. Otherwise the temperature falls, and the liquid becomes cooler.

Evaporation of any liquid lowers the temperature. Thus the evaporation from the surface of the body tends to lower the temperature of the body. At all times, whether we are warm or cold, we are perspiring, but evaporation takes place just as fast as the perspiration exudes, and we do not have the sensation of dampness.

A healthy person perspires an amount between a pint and a quart every twenty-four hours. A man violently exercising may perspire over four quarts in a day.

A current of air removes the water vapor and permits a more rapid evaporation of the remaining liquid. Therefore a person is cooler in a draft than in still air, and is liable to reduce his external temperature too rapidly and catch cold, if his clothes are damp.

References: —

1. 1503 : 397-398.	Regulation of Body Temperature.
2. 1803 : 100-101.	Cooling Effects of Evaporation Explained.
3. 1803 : 210.	Intense Cold by Evaporation.
a. 1507 : 241-244.	Perspiration as a Heat Regulator.
b. 1801 : 281.	Cold by Evaporation.
c. 1804 : 289.	Heat Consumed in Evaporation.
d. 1805 : 340.	Cold by Vaporization.
e. 1806 : 365-366.	Cooling by Evaporation.
f. 1807 : 193.	Disappearance of Heat during Vaporization.

25. APPLICATIONS OF EVAPORATION AND CONDENSATION

As fast as man really understands the phenomena of nature, he makes use of them for his own comfort, or for profit. Accordingly, life means most to the one who knows most, and can use his knowledge in his daily life. Cooling by evaporation, and the reverse, that is, warming by condensation, are but two more examples of the application of knowledge to practical ends.

The saying that it is a poor rule which does not work both ways applies more strictly to science than to anything else. In fact, there are but few physical or chemical changes of form or energy which are not reversible. Evaporation requires heat; that is, heat is absorbed by the material which is evaporating. When this vapor is condensed, exactly the same amount of heat is given out. There is no loss in nature.

If water is placed in a porous earthen jar, the water which seeps through evaporates into the air and cools the remainder. The drier the air, and the more air that is brought into contact with the surface of the water, the lower will become the temperature.

Milk may be kept from souring, and butter may be preserved in a more solid condition, by being placed in a saucer of water and wrapped with a cloth which is kept damp by the water in the saucer. Cooling closets are constructed on the same principle; that is, a light framework is covered with sacking which is kept moist by a tank on top. The heat which the water requires in order to become a vapor is taken from the food within the closet, and thus the food becomes cooled.

Those liquids which have the tendency to evaporate easily necessarily lower the temperature of their surroundings more than does water when it evaporates. Ether, alcohol, and any of the volatile liquids do this to a very marked degree. It is quite easy to freeze water by means of the evaporation of ether.

The liberation of heat by condensation is made use of in the system of steam heating. Water is boiled in a boiler, and a large amount of heat is absorbed in changing the water to steam. The steam passes through pipes to the colder parts of a building and condenses to water, thereby giving up to the air of the rooms all of the heat which it had absorbed from the fire. The water which leaves a radiator may be of the same temperature as the steam which entered, although it has given up a vast amount of heat in its condensation. Dew, in forming, raises the temperature of the atmosphere, and a foggy night is usually warmer than a clear night. Both these facts are due to the principles of condensation already explained.

References: —

1. 1103: 134-135. Formation of Ground Fog Prevents Further Cooling.
2. 1803: 102. Freezing by Evaporation.

3. 1803: 212-214. Liquid Air—Manufactured Ice.
a. 1802: 317. Plan of an Ice Plant.
b. 1805: 351-354. Cold by Expansion—Ice.
c. 1806: 370-372. Steam Heating of Buildings.
d. 1807: 206-207. Cooling by Evaporation—Applications.
e. 1809: 194-195. Ice Machines.

Experiment 15. — Cooling by Evaporation.

Apparatus: Beaker 50 c.c., test tube $6'' \times \frac{3}{4}''$, syringe bulb with rubber outlet tube, glass tube $\frac{1}{4}''$ diameter, 6" long.

Materials: Ether, alcohol.

a. Pour a little alcohol on the hand, and wave it. Repeat, using ether. What is the difference? Why?
b. Put 20 c.c. ether in the beaker, and place in it the test tube containing not more than 2 c.c. cold water; gently force air through the ether by means of the bulb, using the glass tube in the ether. The water should freeze in about ten minutes.

Experiment 16. — Heating by Condensation.

Apparatus: Burner, ring stand, asbestos mat, flask 250 c.c., single-hole rubber stopper to fit flask, glass tube $\frac{1}{4}''$ diameter, water trap, rubber tube in short pieces to join glass tubing, beaker 150 c.c., thermometer.

a. Boil water in the flask and pass the steam, by means of the glass and rubber tubing, through the water trap, into 100 c.c. water which has a temperature of 47° C., until the temperature becomes 99° C. Measure the water in the beaker. How many grams of water were condensed? To raise 100 c.c. of water from 47° C. to 99° C. required how many calories? Divide this number by the number of grams of water which were condensed, and you will obtain the number of calories which each gram of steam gave up while condensing. What results did you obtain? How does this compare with your references?

26. THE STEAM ENGINE

Another application of the laws of nature is instanced in the case of the steam engine. When a liquid evaporates, the average velocity of its molecules is much greater than that which they had in liquid form. When these rapidly moving molecules strike the walls of any container which restrains them from unlimited motion, they exert a pressure upon the walls that is proportional to their velocity. The latter increases with the temperature. When water is boiled, evaporation takes place rapidly, and the steam may also be heated far above the boiling point. Therefore we can obtain any pressure we may desire.

The steam so generated is conducted alternately, by means of automatic valves, to the opposite sides of a moving piston which slides in a cylinder. The references give complete details concerning various kinds of steam engines.

References: —

1. 1803 : 186-191. The Steam Engine.
- a. 1801 : 297-299. The Steam Engine.
- b. 1804 : 308-313. The Steam Engine and the Locomotive.
- c. 1805 : 312-314. The Steam Engine.
- d. 1806 : 381-386. The Steam Engine.
- e. 1807 : 212-213. The Steam Engine.
- f. 1808 : 245-247. The Steam Engine.
- g. 1809 : 203-207. The Steam Engine.
- h. 1810 : 190-193. The Steam Engine.

27. DISTILLATION OF LIQUIDS

There is very little water which does not contain some solid dissolved in it. It may be purified, however, both by natural and by artificial methods. The evaporation from the

ocean, and other large bodies of water, is nature's great process of distillation. Rain water, falling after a long period of rain, is practically pure. Waterfalls and rapids cause the oxygen of the air to mingle with the water and remove the impurities by a process of combustion. Man purifies water by boiling it and condensing the steam. If water boils slowly, nothing but pure water passes off, except dissolved gases and any liquid which has a lower boiling point than water, all the solid impurities being left behind. If the steam is condensed, we have what is called distilled water, and it tastes very flat, as it has no air dissolved in it. Any material which can be readily changed from a liquid to a vapor may be distilled. Natural, sparkling water has quantities of air, and sometimes carbon dioxide, dissolved in it.

References: —

1. 1703 : 45-47. Distillation of Water.
2. 1803 : 210-211. Distillation of Water.
 - a. 1701 : 50-51. Distillation.
 - b. 1702 : 56-57. Distillation of Water.
 - c. 1704 : 28-29. Distillation of Water.
 - d. 1704 : 211. Distillation of Alcohol.
 - e. 1706 : 39-40. Distillation of Water.
 - f. 1707 : 69-70. Distillation of Water.
 - g. 1708 : 30. Distillation.

Experiment 17. — Distillation.

Apparatus: Ring stand, burner, asbestos mat, flask 250 c.c., rubber stopper with one hole, glass tubing $\frac{1}{4}$ " diameter, rubber tubing, to make connections, test tube 6" \times $\frac{3}{4}$ ", beaker 150 c.c.

Materials: Table salt, molasses, yeast.

a. Fill flask one half full of salty water, which is dirty (a small amount of mud may be placed in the water), insert stopper, fitted with glass tube, connect by means of the rubber

tubing with another glass tube placed in a test tube, and place the test tube in the beaker half full of cold water. Boil the water in the flask only so fast that no steam will come from the top of the open test tube. Compare the condensed water with the water which is in the flask. Taste a little and state how it seems. Place your thumb over the top of the test tube and shake the distilled water for a short time. Taste again and explain the results.

b. Mix a tablespoonful of molasses with a pint of water and half a yeast cake, and allow fermentation to take place for two days. Use the resulting mixture in the place of the dirty salt water, but heat more gently. As soon as you obtain a few drops of distilled liquid, pour it out on the flat base of a ring stand and touch a match to it. What happens? What is it?

28. DESTRUCTIVE DISTILLATION

In the preceding parargaph we considered simple distillation, in which the material was not changed but merely separated physically. It is possible, however, to carry distillation so far that the substance heated is broken up chemically, and the resulting products may be entirely different from the original substance. This is called destructive distillation, and the products obtained by this process are often very valuable.

The destructive distillation of soft coal gives gas, coal tar, coke, carbon, and other by-products. Wood yields a gas, wood tar, acetic acid, and wood alcohol. Petroleum yields several volatile liquids, such as gasoline, naphtha, benzine, and kerosene. The solid remainder is paraffin in some petroleums and asphalt in others. See Section 137, Coal, Soft and Hard, and Section 138, Petroleum and Natural Gas.

References:—

1. 1503 : 189-190. Destructive Distillation of Wood.
2. 1710 : 53-54. Illuminating Gas from Soft Coal.
3. Circular 114. Forest Service, U. S. Dept. of Agriculture.
 - a. 1704 : 168-169. Destructive Distillation.
 - b. 1706 : 188-189. Formation of Charcoal and Coke.
 - c. 1708 : 82-83. Carbon from Other Compounds.
 - d. 1709 : 374-377. Destructive Distillation.
 - e. 1712 : 255. Destructive Distillation.

Experiment 18. — Destructive Distillation.

Apparatus: Burner, test tube $6'' \times \frac{3}{4}''$, test-tube holder, ordinary clay pipe.

Materials: Chips of wood, soft coal, rice, sugar, starch.

a. Place a few chips of wood in a test tube and heat it gently. Notice what collects on the upper part of the tube. Where did it come from? Heat more strongly, moving the tube through the flame so as to heat it uniformly. As soon as the smoke becomes quite dense, light it. What does a flame indicate always? Continue to heat the wood, until no more smoke comes off, and then examine the residue. What is it?

b. Repeat with rice, sugar, and starch. (Different pupils may use different materials and compare notes, in order to save time and material.) What are your conclusions in regard to all of the substances which have been heated?

c. Place a few very small pieces of soft coal in the bowl of a clay pipe, cover with wet clay (mud will do) and heat strongly. The gas will burn at the mouthpiece for a considerable time. After the gas ceases to be evolved, examine the residue. Try to burn the residue. Remembering Paragraph (e) in Experiment 5, draw your conclusions.

29. COOKING

There is one other effect of heat which civilized man employs, and which is a strong civilizing influence: heat changes food so as to render it more soluble in the digestive juices, and at the same time kills all microbes in the food, thus preventing disease from entering the system. Cooking, which is the result of the application of heat to food, falls under two general headings — boiling and baking. Boiling has the advantage of constant temperature, which is, ordinarily, 212° Fahrenheit. Fast boiling is not hotter than slow boiling, if the dish is uncovered. Covering a dish raises the temperature of the boiling water, since the cover prevents rapid radiation of heat.

Roasting or baking takes place at varying temperatures, according to the kind of food which is being cooked. It is to be remembered that it is the temperature which does the cooking, or, to put it another way, the chemical changes which are called cooking take place at a certain temperature for a given kind of food. Therefore, if we can only keep food hot, without a fire, that food will be cooked just as well as it would be in a stove. This is the principle of the so-called fireless cooker. After the food to be cooked has been heated to the boiling point, we place it in receptacles surrounded by nonconductors of heat; thus the heat which is already in the material stays there, and chemical changes take place which result in cooking. It is not necessary to have elaborate fireless cookers. Boxes well packed with excelsior, or felt from a hat manufactory, and provided with a tight-fitting cover, also well packed, will serve.

Here are a few of the principles of cooking :—

1. If meat is to be cooked for a stew, the pieces should be cut small and put in cold water over a slow fire. This allows the juice to come out. Salting the water will increase the flow of the juice and make the meat more tender, since the addition of salt raises the boiling point of water.

2. If the cooking water is to be thrown away, the meat should not be put in until the water is boiling very rapidly. If the meat is in a large piece, it should be seared all over in a smoking-hot pan before boiling. This keeps in the juice.

3. To prepare a roast, the oven should be very hot at the beginning and a little cooler after the first half hour. The intense heat sears the outside of the meat, as in the case above.

4. In frying meat, the frying pan should be very hot at first and then cooler after both sides of the meat have been seared.

5. Bread requires the hottest possible oven; pies should be baked in an oven which is a little cooler, while cakes, as a rule, do not need a very hot oven. When cakes break open, it is because the oven is so hot that the outside of the cake bakes before the mass has time to rise.

References: —

1. 1501 : 52-53. Cooking and Ways of Cooking.
2. 1702 : 383-387. Chemical Changes in the Cooking of Food.
3. 1710 : 121. Necessity for Cooking.
4. 1803 : 204-205. Boiling Point Defined.
5. 1901 : 172-175. Heat Destroys Bacteria.
6. Farmers' Bulletin No. 34 : 14-19. The Cooking of Meats.
7. Farmers' Bulletin No. 256 : 9-13. General Principles Underlying Vegetable Cooking.
 - a. 1505 : 114-115. The Five Modes of Cooking.
 - b. 1506 : 44-45. Ways of Cooking.
 - c. 1507 : 53-56. Cooking a Safeguard.
 - d. 1508 : 71-72. Effects of Cooking.
 - e. 1805 : 337-338. Laws of Ebullition.

EXPERIMENT FOR THE HOME**Temperature Causes Cooking**

- a. Place an egg in boiling water and boil it for exactly four minutes. Open the egg immediately after removing it from the water and note its texture.
- b. Place another egg in one pint of boiling water and remove from the source of heat. Allow egg to remain in the cooling water for ten minutes. Open egg immediately and compare it with the first egg. How much water would be necessary to cook eight eggs by this method? Would there be any difference in the result if the egg had been in an ice-chest?

Eggs cooked at a lower temperature are not only pleasanter to eat than eggs boiled rapidly, but they are also more digestible; that is, the consumer obtains more nourishment from such an egg at less expenditure of digestive energy.

30. CHEMICAL AND PHYSICAL CHANGES

Changes within the molecule which alter its composition are called chemical changes. After such changes the material is entirely different from what it had been, and is, in fact, a new substance. Examples of chemical change are the souring of milk, decay of food, rotting of wood, formation of coal from wood, destructive distillation, the bleaching of any material, and any action which involves a permanent change.

Physical changes are concerned with the molecules as a whole, and are limited to the different arrangement of the molecules, or their relative velocities. Physical changes are often temporary, such as the melting of ice and the freezing

or boiling of water. The color of some materials is altered by heat or dampness, but returns to its original tint or shade when the temperature is lowered or the dampness driven off.

References: —

1. 1703 : 2-4. Relation between Chemistry and Physics.
- a. 1701 : 2-3. Chemical and Physical Changes.
- b. 1702 : 1-3. Physical and Chemical Changes.
- c. 1704 : 7-8. Chemical and Physical Changes.
- d. 1705 : 3-5. Physical and Chemical Changes.
- e. 1706 : 1-2. Physical and Chemical Changes.
- f. 1707 : 2-3. Chemical and Physical Changes.
- g. 1708 : 2. Physical and Chemical Changes.
- h. 1709 : 1-2. Physical and Chemical Changes.
- i. 1711 : 23-27. Physical and Chemical Changes.
- j. 1712 : 13-14. Physical and Chemical Changes.

Experiment 19. — Physical and Chemical Changes.

Apparatus: Burner, tweezers, test tube, $6'' \times \frac{3}{4}''$, test-tube holder.

Materials: Mercuric oxide, strips of copper $6'' \times \frac{1}{2}''$.

- a. Barely cover the bottom of a test tube with mercuric oxide, and heat gently. Note change in color. What is it an example of? Let the test tube cool a little and see if what you expect happens.
- b. Heat the test tube strongly for several minutes and tell what happens to the mercuric oxide. The material on the sides of the test tube is mercury. Examine it. Mercuric oxide is a compound of mercury and oxygen. Where is the oxygen? What kind of a change has taken place?
- c. Heat one end of the copper strip until the other end is too hot to hold in the hand. Let it cool. Is this a chemical change or physical change?
- d. Hold one end of the copper strip by the tweezers and ...

the other end in the flame. Heat for ten minutes or more. Watch the color of the copper strip. Examine the heated end after ten minutes. Bend this end back and forth, and explain what you notice. Give it a name. What makes you think so?

31. CHEMICAL COMBINATION PRODUCES HEAT

One form of chemical action was studied in Section 4, Combustion. There we learned that the union of oxygen and some combustible produces a large amount of heat. From the little you have studied of general science, you would expect that any chemical union would produce heat. This is true in all cases where there can be no further chemical change. The heat is not always apparent nor of the same quantity as in the oxidation of substances, but it is quite noticeable in several instances.

Sulphuric acid and water when poured together form a chemical union which liberates a large quantity of heat. Balloonists make use of this method of obtaining heat without a fire, which would be dangerous. Many of the common metals and acids combine and liberate heat. A gas, hydrogen, is also set free. This gas will be studied in Section 114, Composition of Water.

References: —

1. 1703 : 220. Heat of Formation and Decomposition.
a. 1701 : 75-76. Heat of Reaction.
b. 1704 : 318-319. Thermal Relations of Chemical Changes.
c. 1705 : 147-150. Heat of Chemical Changes.
d. 1706 : 112-113. Heat and Chemical Action.
e. 1708 : 117-118. Heat of Chemical Action.
f. 1709 : 218-219. Heat of Formation.

EXPERIMENTS FOR THE TEACHER

Use a thermometer with large index, and show the high temperature produced by pouring sulphuric acid into water (use care); try hydrochloric acid and zinc, sulphuric acid and iron; mix equal parts of potassium chlorate and sugar together, place on iron pan, and add a few drops of sulphuric acid, *at arm's length*. Add a small piece of metallic sodium to water. The hydrogen, set free, ignites spontaneously.

32. FRICTION AND COMPRESSION PRODUCE HEAT

When one body rubs against another, there is a certain resistance which depends upon the force of contact and the surface quality of the bodies. We call the cause of this resistance *friction*. Since the molecules which are on the surfaces of the two bodies are caused to move more rapidly, heat is produced. Examples: production of fire by the rubbing together of two sticks, and also by the use of flint and steel.

If we hammer a piece of lead, we force the molecules to slip by one another and give them an added velocity, which becomes apparent as heat. Thus there can be external and internal friction, but the result is always a production of heat.

Since molecular motion is heat, we should expect that if we could increase the number of molecules within a given space, the temperature would rise. The only way in which this object can be accomplished is by compression. If we compress a gas, it becomes hotter. Conversely, if the gas is allowed to expand, it becomes cooler. Refrigerating plants and ice machines are founded on this principle. Ammonia gas is compressed and then is allowed to expand in the desired place, which lowers the temperature of that place consider-

ably below the freezing point of water. Carbon dioxide may be obtained in liquid form in steel tanks. If this liquid is allowed to expand, so much heat is required that it turns to a white solid at a temperature of -80° C. Mercury may be frozen by the removal of the heat required to evaporate solid carbon dioxide.

References: —

1. 1002: 393-395. Heat of Sun Due to its Contraction.
2. 1103: 49-50. Heating by Compression and Cooling by Expansion in the Atmosphere.
3. 1803: 176. Heat Developed by Friction.
4. 1803: 177-178. Heat Produced by the Compression of a Gas.
5. 1803: 178-179. Cooling by Expansion.
6. 1803: 210. Intense Cold by Evaporation and Expansion.
 - a. 1805: 307-309. Heat Produced by Friction and by Compression.
 - b. 1807: 161-162. Heat from Friction.
 - c. 1808: 214-215. Friction and Compression as Sources of Heat.

EXPERIMENTS FOR THE HOME

Rub a coin on the coat sleeve; hammer a piece of lead. Notice that a bicycle pump becomes warm, during use, and note that the connecting tube also is heated.

Try to obtain a lead bullet immediately after it has struck an iron target, and note its appearance as well as its temperature. Explain its appearance. Why would the results not be the same with a wooden target?

Observe that in all of the given examples motion has been changed into heat, that is, molar or mass motion is transformed into molecular motion.

EXPERIMENTS FOR THE TEACHER

Obtain a five-pound tank of carbon dioxide and a small flannel bag. Tie the bag over the outlet of the tank, tipping the tank so that the outlet is lower than the rest of the tank. Open wide the stopcock for half a minute. If there is not enough solid, repeat. Put some mercury in a test tube and place the test tube in a beaker half full of ether, containing the carbon dioxide. When the mercury is frozen, break the test tube and drop the solid mercury on the table like any common metal.

33. RADIUM PRODUCES HEAT

Radium was for some time one of the curiosities of the chemical world. Since it produced elements different from itself, it seemed to be an exception to general rules governing elements. We now know that other elements act in a similar manner, although not to such a marked degree.

Radium can produce chemical changes in a covered photographic plate, and excite fluorescence in some substances. This is accomplished by the emission of rapidly moving particles and by some rays which are similar to Röntgen, or X-rays. The particles form a gas called *helium*.

Since heat is due to the motion of the molecules, the liberation of rapidly moving particles produces so much heat that the temperature of radium is always 5° F. or 2.7° C. higher than its surroundings. The amount of heat liberated by one gram of radium is 100 calories per hour. Thus radium can melt one and one fourth of its own weight of ice every hour. It is not possible to utilize this heat for practical purposes.

References: —

1. 1002 : 396. Theory — Heat of Sun Partly Due to Radium.
2. 1803 : 476-482. Radium and its Transformations.
 - a. 1001 : 157. Contraction and Radium Produce Sun's Heat.
 - b. 1809 : 434. Heat from Radium.

34. THE SUN

Our sun is a vast sphere, one hundred and ten times the diameter of the earth, and more than one million times its volume. It rotates on its axis once in twenty-five and one fourth days, and is distant about ninety-two million miles. It is so hot that all the material of which it is composed exists in the form of a gas or vapor. The heat is probably caused by a contraction due to gravitation, the compression being sufficient to produce the high temperature. The emanations from radium may produce some of the heat, as radium has been discovered in the sun.

References: —

1. 1002 : 105-106. Heat of Sun.
2. 1002 : 387-390. Heat of Sun.
3. 1002 : 390-391. Temperature of Sun.
4. 1002 : 410-416. Constitution of Sun.
5. 1103 : 25. The Apparent Motion of the Sun around the Earth.
6. 1304 : 9-10. Heat of Solar System.
7. 1601 : 3-9. Sunshine.
 - a. 1001 : 154-155. Temperature of the Sun.
 - b. 1001 : 155-156. Constancy of Sun.
 - c. 1001 : 156-157. Age of Sun.
 - d. 1001 : 157-160. Constitution of Sun.
 - e. 1003 : 110-111. Source and Duration of Sun's Heat.
 - f. 1004 : 166-167. Temperature of Sun.
 - g. 1004 : 168-169. Age of Sun and Maintenance of Heat.

- h.* 1207 : 253-257. The Sun as a Source of Heat.
- i.* 1301 : 55-57. Heat of Sun.
- j.* 1807 : 211. Source of the Sun's Energy.
- k.* 1810 : 398. Composition of the Sun.

35. THE SUN THE SOURCE OF ALL ENERGY

As previously stated, the sun sends out energy, which is transformed into various other kinds of energy. It is quite probable that the original energy is electrical, and that its products depend upon the various conditions it meets. These products may be enumerated as follows:—

1. *The Sensation of Light.* Light in itself is invisible. Certain wave lengths of electrical energy enter the eye and produce their effect, according to the length of the waves, and the amount of energy which affects the retina, or sensitive part of the eye. We see objects by reflected light. We really do not see the objects themselves. All light produced on earth owes its energy originally to the sun.

2. *Heat.* This is produced when the electrical energy strikes anything which retards it. If it strikes an opaque object, all the energy is stopped, and the result is the greatest possible amount of heat. If the object is transparent, most of the energy will pass through; very little will be stopped, and the material will not become very warm. The amount of heat produced by the energy of the sun varies from a very little, in the case of transparent material, to a great deal, in the case of opacity. An excellent example of this is to notice how warm we become when we stand by a closed window in the sunshine, and then to observe that the glass, through which this energy comes, is quite cold. This is absolute proof that heat from the sun does not come to us as heat, but as energy, which is doubtless electrical.

3. *Change in chemicals*, which enable us to use the art of photography, and other changes, a study of which belongs particularly to a chemistry course.

4. In plants also, much of the *growth*, and nearly all of the *nourishment*, are dependent upon chemical changes which the energy of the sun causes in them. Plants cannot take up the carbon from the air, nor can they change starch to sugar, necessary for plant growth, without the sunlight or some other very powerful light, as, for instance, the electric arc.

5. Electrical energy from the sun probably causes *terrestrial magnetism*. It has been noticed whenever there are sun spots that the magnetism is affected, proportionally to the size and duration of the sun spots. In this connection it is quite likely that the aurora borealis and the aurora australis owe their existence to the same cause.

References: —

1. 1002 : 414-416. Description of Sun Spots.
2. 1103 : 27. Solar Constant.
 - a. 1001 : 124-127. Nature of Sun Spots.
 - b. 1001 : 131-132. Cause and Influence of Sun Spots.
 - c. 1003 : 106-110. Sun Spots Show Rotation of Sun.
 - d. 1004 : 143-144. Terrestrial Influence of Sun Spots.
 - e. 1207 : 74-75. Explanation and Effects of Sun Spots.
 - f. 1301 : 53-54. Magnetism and the Northern Lights.
 - g. 1306 : 8. Sun Spots.
 - h. 1806 : 376-378. The Sun our Main Source of Energy.

36. THEORIES

From time immemorial, man has wondered about the laws and phenomena of nature. His conjectures, somewhat hazy at first, and more scientific as the ages passed, always concerned the same questions: the source of the world; why the

world revolved; whether the world was always in its present state; what the stars were; what the sun was. The conclusions that he drew were at first very erroneous, as any student of mythology knows. Yet the great thinkers, working from what they learned through history, physics, chemistry, have formulated certain theories which may explain our solar system and its formation. There is hardly a scientist who will have the temerity to say that any given theory is absolutely correct, yet all these theories are very reasonable and are supported by such an immense number of facts that they are probably correct to a very great extent. Theories must precede practice, and are very valuable as a starting point for scientific investigation.

References: —

1. 1002 : 441-443. The Advantages of Theories.
 - a. 1701 : 64. Value of a Theory.
 - b. 1705 : 89-90. The Necessity of Theories.
 - c. 1712 : 7. The Definition of a Hypothesis.
 - d. 1801 : 3. Theory Defined.
 - e. 1807 : 145. The Meaning and Value of a Theory.
 - f. 1808 : 11. Hypotheses, Theories, Laws.
 - g. 1809 : 5-6. The Theoretical Methods of Physics.

37. THE LAWS OF MOTION

All heavenly bodies obey the laws of nature in the same way as do small bodies. It may be well to consider what is meant by the law of nature, or, as it is sometimes called, natural law. A man-made law is a rule of conduct; nature's laws, as they are formulated by man, are merely statements of facts. Man has made the discovery that certain results come from certain causes. His discovery does not make nature act that way, for nature has always acted

in the same way. Thus, when we study any natural law, we must not for a moment think that nature has to act that way, but simply that nature does act that way, and that in these laws there never have been, and never will be, any exceptions.

The laws of motion are absolutely unalterable, and were discovered and stated first by Sir Isaac Newton. They are, therefore, called "Newton's Laws of Motion," but Newton did not make them. His experiments showed him that bodies in motion always behaved in a certain way, and he put his observations into concise form and called them the "Laws of Motion."

References: —

1. 1002 : 145-147. The Laws of Motion.
2. 1803 : 32-36. Newton's Laws of Motion.
 - a. 1001 : 72. The Law of the Earth's Motion.
 - b. 1003 : 81-82. The Laws of Motion.
 - c. 1801 : 29-31. The Laws of Motion.
 - d. 1802 : 56. Newton's Laws of Motion.
 - e. 1804 : 65-69. Newton's Three Laws of Motion.
 - f. 1805 : 49-50. The Laws of Motion.
 - g. 1807 : 83-92. The Laws of Motion.
 - h. 1808 : 39. Newton's Laws of Motion.
 - i. 1809 : 65-72. Laws of Motion.
 - j. 1810 : 36-37. Newton's Laws of Motion.

Experiment 20. — Inertia and Reaction.

Apparatus: Card, coin, iron ball with screw eyes at the two ends of a diameter, string, a piece of clock spring, two small blocks of wood of unequal size.

a. Balance coin on card on end of finger, and snap card out. Coin will remain on finger, if care is used. If this is found to be too difficult, place coin on card on corner of a table, and knock the card off, horizontally.

b. Support iron ball by small string and tie another piece

to the under side of the ball. Pull slowly on the bottom string. Which string breaks? Why? Pull very suddenly on the lower string, and explain results.

c. Bend a piece of clock spring about eight inches long into the form of a V. Put it between two blocks, of unequal size, compress and release. Note the different distances which the blocks moved. Repeat this several times, and give an explanation.

38. EFFECTS OF TWO OR MORE FORCES ACTING AT THE SAME TIME

If two or more forces are acting on a body, each force acts independently of all the other forces. That is, the final position of the body will be the same as it would have been if one force had acted alone, stopped, and then each of the other forces had acted successively.

This fact is stated in Newton's Second Law of Motion. Examples are everywhere present if we do but notice them. For instance, when a person crosses a moving car, the final position he will occupy will be the same as it would have been if he had crossed the car after it stopped. The graphical representation of two or more forces acting together is given in Section 97, Resolution of Forces.

References :—

Any reference in Section 37.

EXPERIMENT FOR THE TEACHER

Newton's Second Law of Motion

Use the standard machine to illustrate, and repeat at least three times, trying the different positions of the trigger. Be sure that the machine is horizontal.

39. UNIVERSAL GRAVITATION

Gravitation is the name given to the force which acts among all bodies of matter, tending to bring them together. We who live on the earth are inclined to think that the earth attracts us. While this is true, it is just as much a fact that the earth is attracted by us. Gravitation, then, is the mutual action which takes place between every two bodies of matter. By careful measurements, it has been found that the changes of gravitation vary as the product of the masses of the two bodies, and inversely as the square of the distance between them.

Not only is this force of gravitation acting between the earth and the bodies on it, but it acts between all of the heavenly bodies. Thus the sun attracts the earth, and the earth attracts the sun; the moon attracts the earth, and the earth attracts the moon. The question which naturally arises is, Why do not these bodies come together? The answer is that they would come together if they were not in rapid motion, whirling around each other. Part of the year the earth and the sun do come closer together than at other seasons, but the velocity of the earth is great enough to take it entirely around the sun, and thus avoid any collision. This is one of the proofs that the earth revolves around the sun once a year, for if this revolution did not take place, the earth and the sun would fall together. Yet as the earth revolves around the sun, its path is not that of a smooth curve, nor is it the same from year to year. The other planets attract the earth, and the earth attracts the other planets, so that the earth moves in a wavy path approximating an ellipse. In the same way, the moon does not revolve around the earth in a symmetrical curve, but moves in a wavy path.

References: —

1. 1002 : 194-200. The Law of Gravitation.
2. 1304 : 8-9. Gravity and Gravitation.
3. 1803 : 20-21. Newton's Law of Universal Gravitation.
 - a. 1001 : 51. Gravity.
 - b. 1801 : 48. Law of Universal Gravitation.
 - c. 1802 : 86. Law of Universal Gravitation.
 - d. 1804 : 118-121. Universal Attraction between Masses.
 - e. 1805 : 48-49. Gravitation.
 - f. 1806 : 91-92. Direction of Gravitation and Center of Gravity.
 - g. 1807 : 98-99. Universal Gravitation.
 - h. 1808 : 60-61. Gravitation and Gravity.
 - i. 1809 : 110. Newton's Law of Universal Gravitation.
 - j. 1810 : 33-34. Universality of Gravitation.
 - k. 1811 : 330-335. Gravitation.

40. THE CENTER OF GRAVITY

The center of gravity is the point which, if supported, will prevent the entire body from falling. It may also be defined as that point where we may consider all the weight of the body located. In a sphere it is at the center; with an irregular body the center of gravity may be entirely outside the body.

The center of gravity of a small body may be located by suspending the latter by a string. If the string is imagined to be prolonged into the body, it will pass through the center of gravity. By supporting the body from at least three different points, the center of gravity is definitely determined.

References: —

1. 1803 : 22-23. Center of Gravity and Method of Finding It.
 - a. 1801 : 48-49. Center of Gravity.
 - b. 1805 : 50. Center of Gravity.

- c. 1906: 92-93. Center of Gravity.
- d. 1907: 60-61. Center of Gravity.
- e. 1908: 63-64. Center of Gravity.
- f. 1909: 55-56. Center of Gravity and Methods of Locating It.
- g. 1910: 13-14. Center of Gravity and Method of Finding It.

Experiment 21. — Center of Gravity.

Apparatus: Bottle, two cork stoppers, two knives or table forks, pin, needle.

a. Place one stopper in the bottle and stick the pin into it. Into one end of the other cork pass the needle, head first, and stick the knives or forks into the opposite sides of the cork so that they hang in a slanting direction. If the point of the needle is placed on the head of the pin, the whole system will balance. Devise some method of balancing a half dollar, on its edge, on the rim of a table glass. If the center of gravity of any system is low, the whole system is stable and will balance.

41. THE EFFECT OF TWO FORCES ACTING AT RIGHT ANGLES TO EACH OTHER

The second law of motion states that each force acts independent of any other force. See Section 38. If the forces act at right angles to each other, a curved motion is produced which may be a closed curve, like the circle or the ellipse, or an open curve, of which the parabola and the hyperbola are examples.

The earth is held in its path around the sun by means of the attraction which the earth and sun have for each other,— gravitation,— while its forward motion continues on account of its inertia. Refer to Section 37. A more complete discussion of the earth's motions is given in Section 50, The Motions of the Earth.

If the forward motion of a body, either on earth or in the heavens, is great compared with the force of attraction, the body passes beyond the effective action of the latter force, and, in the case of the heavenly bodies, may never return. Some comets act in this manner. See Section 57, Comets.

References: —

1. 1803 : 19-20. Pendulum Motion Analyzed.
- a. 1801 : 60. Curvilinear Motion.
- b. 1804 : 24-25. Rectilinear and Curvilinear Motion.
- c. 1805 : 63. Motion of a Pendulum.
- d. 1807 : 93-97. Curvilinear Motion.
- e. 1808 : 49. Curvilinear Motion.
- f. 1809 : 113. Curvilinear Motion.

EXPERIMENT FOR THE HOME

Swing a stone at the end of a weak string. Note the pull which is necessary to make the stone continue in a circular path.

Make the stone revolve faster until the string breaks. In this case the forward motion is too great for the force acting at right angles to it to be affected by the pull of the string. Note that the stone moves off in a straight path. This is due to the fact that the effect of the string ceases as soon as the string breaks. Gravitation decreases gradually, and, even in the case of very rapidly moving comets, produces a slightly curved path.

42. THE MEASUREMENT OF ROTARY MOTION

The motion produced by turning a body on an axis is called *rotary motion*. If a certain point on the outside of the body moves until it returns to its original position, we say that the

body has made one revolution. It is easy to count the revolutions, but we sometimes desire to measure rotary motion in fractions of a revolution.

A complete revolution is called 360° . One quarter of a revolution, therefore, is 90° . Each degree is divided into 60 equal parts called minutes, meaning small. The minute was found not to be small enough, and a second division was made which consists of the 60 equal parts of the minute, which are called seconds.

Not only is rotary motion measured by this means, but the same system is used to indicate direction. Thus a road may cross another road at what is called an angle of 30° . This means that a wagon, in going from one road to the other, must turn 30° in order to take the desired direction. We reckon direction, in regard to the north and south line, by this same system. See Sections 49 and 61.

Altitude may be given in feet, or other units of length, or it may be stated in degrees, minutes, and seconds. We can say that a building is 62° high, from a certain position, which means that it is necessary to raise our eyes 62° above the horizontal plane in order to see the top of the building.

References:—

Any text in Geometry. See Angular Measurement.

1. Forest Service Bulletin 36 : 98-106. Instruments for Measuring Heights.

Experiment 22. — To Make and Use a Clinometer.

a. On a piece of cigar-box wood $6'' \times 4''$ draw a semicircle with the center at the middle of the long side. Mark every 5° with the protractor and number from the right angle mark, each way, 0-90.

Drive a brad at the center of the semicircle and one at each

90° mark. Tie a small weight to the middle brad, using a piece of string more than 6" long. When the three brads are horizontal, the string should cross the 0 degree mark.

b. Holding the instrument in the left hand, sight along the three brads at some elevated object and read where the string crosses the degree marks. This is the angular altitude from that position. Approach the object and again sight. Why is there a difference? Has the object become taller?

c. "Sight" at the sun. To do this hold a piece of paper near one end of the clinometer and obtain the three shadows of the brads in the same place. The reading indicates the altitude of the sun. Walk toward the sun and obtain its altitude. Is there any difference? Explain. Wait half an hour and repeat, giving an explanation of the results.

43. THEORIES OF THE EVOLUTION OF THE SOLAR SYSTEM

There are two general theories which must not be accepted as facts, but as theories. There is much which supports each of these theories, and likewise there are many things which are not explained by either of them.

La Place formulated a Ring Hypothesis, which, stated briefly, is as follows: In the beginning there was a large mass of heated gaseous material which began slowly to revolve, and as it cooled it contracted. As the contraction took place the motion became faster and faster, until the centrifugal force was greater than the gravitational force, so that a ring around its equator was thrown off into space. Ring after ring left the parent mass, each ring contracting into a sphere, one of which is the earth. The other planets were formed in the same way. There remained a central mass, which is our present sun.

Lockyer and Darwin modified this theory by considering that the material originally was in the form of cold meteors. These, on account of the distance between the separate meteors, would act like a gas, and the heat could have been produced by the collision and compression of a large number of these meteors. Thus there was no necessity for original heat. This theory has been given the name Meteoritic Hypothesis.

Lastly, a modification of the La Place Hypothesis states that the material was not in equilibrium at the beginning, but whirling in a vast spiral, the different parts of the spiral breaking up to form the Solar System. This is called the Spiral Nebular Hypothesis.

Since we are considering the beginning of things, a definition of the word *evolution* might not be out of place. By evolution is meant the slow change from the simple and unorganized to the complex and highly organized. Such a change usually takes a very long period of time, which cannot be reckoned in years, but in millions of years.

References: —

1. 1002 : 446-449. La Place Ring Hypothesis.
2. 1002 : 448. Meteoritic Hypothesis.
3. 1002 : 453-458. La Place Ring Hypothesis.
4. 1002 : 463-466. Spiral Nebular Hypothesis.
5. 1002 : 485-487. The Past and Future of the Solar System.
6. 1205 : 304-305. The Earth's Beginnings.
 - a. 1001 : 353-356. Genesis and Nebular Hypothesis.
 - b. 1003 : 224. The Nebular Hypothesis.
 - c. 1004 : 351-353. La Place's Nebular Hypothesis.
 - d. 1004 : 353-354. Lockyer's Meteoritic Hypothesis.
 - e. 1301 : 27-31. The Nebular Hypothesis.
 - f. 1305 : 38. The Nebular Theory.
 - g. 1306 : 19-22. The Nebular Hypothesis.

44. THE SOLAR SYSTEM

Up to this time we have looked at natural phenomena from a personal standpoint. We will now consider the real place which we, on earth, occupy in the great system of which we are such a small part.

The solar system consists of the sun and the following planets, named in the order of their distances from the sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune. It is called *solar*, because all of these planets revolve around the sun, and a *system*, because they obey definite laws, returning upon their orbits at regular intervals.

References: —

1. 1002 : 485-487. The Age and Future of the Solar System.
2. 1304 : 3-6. Other Spheres.
 - a. 1001 : 359-360. Age and Duration of Solar System.
 - b. 1003 : 142-144. The Structure of the Solar System.
 - c. 1004 : 188-189. The Planetary System.
 - d. 1004 : 191-192. Gravitation Explains Planetary Motion.
 - e. 1301 : 22-27. The Solar System.
 - f. 1303 : 14. The Solar System.
 - g. 1305 : 35-38. The Solar System.
 - h. 1306 : 5-13. The Solar System, the Earth, and the Moon.
 - i. 1307 : 9-14. The Earth among Planets and the Sun.
 - j. 1309 : 11-17. The Earth and the Solar System.
 - k. 1310 : 320-321. The Solar System and the Stars.
 - l. 1311 : 17-18. The Earth is One of the Planets.
 - m. 1312 : 2. What the Solar System Comprises.

45. THE PLANETS AND THE EARTH

These large bodies of matter are cold, and shine only by reflected light, similar to the light received from the moon. The planets may support life according to the conditions of

the atmosphere and the supply of water. They all rotate on axes, and revolve around the sun. Thus they have day and night, and seasons, although all these periods are entirely different from those of the earth, in length, in degree, and frequency of changes.

Since we live on the earth, we do not think of it as a sphere revolving through space, for it is so large that the small part we see at one time seems flat, while the sun and the stars appear to move around the earth. Nevertheless, the earth behaves like the other planets, and is, after all, one of the smallest ones, Mars and Mercury, only, being smaller.

References: —

1. 1002: 293-297.	Size of the Sun and Distances of the Planets.
2. 1304: 1-8.	The Earth as a Planet.
a. 1001: 199-201.	The Planets in General.
b. 1003: 32-37.	Revolution of the Earth around the Sun.
c. 1003: 142-145.	Structure of the Solar System.
d. 1301: 23-27.	The Planets.
e. 1303: 1-8.	The Earth as a Globe.
f. 1303: 12-14.	Relation of Earth to Other Planets.
g. 1305: 38-41.	The Earth as a Planet.
h. 1305: 43-44.	Rotation of the Earth.
i. 1305: 48-49.	Revolution of the Earth.
j. 1306: 3-18.	The Relation of the Earth to the Planets and the Sun.
k. 1307: 10-14.	The Earth among Planets.

46. AGE OF THE EARTH

The age of the earth must be very great, so great as to be reckoned in millions of years. We know that this is so, for the changes which have taken place upon the surface of the earth could not have been accomplished in any short period of time.

We know that the material of which the mountains are composed was first worn away by streams and then collected at the bottom of the ocean, where it remained for thousands of years. Later, by vast and probably slow convulsions of the earth's surface, it was raised to an elevation far above the present height of mountains. During additional thousands of years these elevations were worn down to their present condition. We have only to observe the erosion of rocks by a stream to realize that the changes such action involves are hardly appreciable in a lifetime. All the manifest alterations of the surface of the earth could, therefore, have been accomplished only in an incredible length of time. Moreover, they must have taken place after the earth finally became cool enough for water to remain on it.

References: —

1. 1205 : 291-294. The Age of the Earth as Shown by Formations.
2. 1205 : 296-297. Fossils and what they Teach. .
3. 1205 : 298-303. Age Great, Known by Slow Change of Species.
4. 1304 : 45-46. Age of the Earth.
 - a. 1201 : 13-17. The Beginning of the Earth.
 - b. 1203 : 150-160. Fossils and their Teachings.
 - c. 1206 : 455-457. Age Determined from Nebular Hypothesis.
 - d. 1210 : 260. The Seven Ages of the Earth.
 - e. 1301 : 236-239. Age of the Earth in Geological Series.
 - f. 1303 : 11. Age of the Earth.

47. THE SHAPE AND SIZE OF THE EARTH

For many centuries the earth was considered flat, and it was believed that the sun went around it. We now know that the sun does not pass around the earth, that the earth

is spherical, and that its rotation on its axis is what gives the apparent motion to the sun. We have some very certain proofs that the earth is spherical: we know that the earth can be circumnavigated, and, moreover, the shadow of the earth upon the moon, no matter when it occurs, always has a circular shape. Again, if the earth were flat, the time of sunrise and sunset would be the same everywhere; but we know that such is not the case. The higher we climb upon a hill, or rise in a balloon, the farther we can see. This is true only because the earth is spherical. The amount of curvature of the earth in feet may be found for the first few miles by squaring the number of miles and multiplying by two thirds. The shape of the earth is not an exact sphere, but is called an *oblate spheroid*, having a polar axis twenty-seven miles less than the equatorial diameter. Thus the land at the poles is thirteen and one half miles nearer the center of the earth than any point on the equator.

References: —

1. 1002 : 114-119. Shape of the Earth.
2. 1002 : 126-127. Size of the Earth.
3. 1304 : 1-3. Shape and Size of the Earth.
 - a. 1001 : 46-47. Size of the Earth.
 - b. 1001 : 52-53. Methods of Determining the Earth's Form.
 - c. 1001 : 56. Shape and Rotation of the Earth.
 - d. 1001 : 58. Surface and Volume of the Earth.
 - e. 1303 : 1-5. Shape and Size of the Earth.
 - f. 1305 : 38-41. Shape and Size of the Earth.
 - g. 1306 : 3-5. Form and Size of the Earth.
 - h. 1307 : 14-15. Form and Size of the Earth.
 - i. 1309 : 18-22. Shape, Size, and Density of the Earth.
 - j. 1311 : 1-2. Form of the Earth.
 - k. 1312 : 16-18. Shape and Size of the Earth.

48. THE HEAT OF THE EARTH

We realize that the earth is very hot inside when we think of volcanoes or even hot springs. In most mines the temperature increases one degree every fifty or sixty feet. If this were continued, the temperature at the center of the earth would be enormously high, but it is probable that at a depth of one hundred and fifty miles the maximum is reached. This is estimated to be seven thousand degrees F. The heat of the earth is probably maintained, to a certain extent, by radium.

Since we know that anything which is hot gradually loses its heat, we can reckon backwards and conclude that the earth once must have been extremely hot. We cannot be sure, however, just how hot the earth has been. Nevertheless, we can believe that it was once in a molten condition.

References: —

1. 1002: 133-135. The Condition of the Interior of the Earth.
2. 1205: 277-280. Conditions of the Interior of the Earth.
3. 1304: 17-18. The Earth's Interior.
4. 1601: 16. The Earth Cooled by Water.
 - a. 1001: 66. Constitution of the Earth's Interior.
 - b. 1207: 88-90. The Result of the Cooling of the Earth's Interior.
 - c. 1302: 28-29. Temperature of the Center of the Earth.
 - d. 1303: 16-17. Underground Temperatures.
 - e. 1305: 41-42. Interior of the Earth and its Crust.
 - f. 1306: 11-12. Temperature of the Earth.
 - g. 1306: 205-206. Interior Condition of the Earth.
 - h. 1309: 40-45. Evidences of Internal Heat.
 - i. 1311: 4. The Earth Within and Without.

49. DIRECTION — LATITUDE AND LONGITUDE

When people began to travel over the seas, it became necessary to locate places on the earth's surface. Since the earth approaches the sphere in shape, any section of it being almost a circle, the system which had been used to measure rotary motion was adapted to this purpose. A starting point was required for the north and south directions, and another for east and west. Nature supplied one, man the other.

Since the equator is halfway between the north pole and the south pole, it was taken as the starting point, and latitude is given in degrees, minutes, and seconds, north or south. It made no difference where the other starting point was taken, so the observatory at Greenwich was called zero, and we now speak of the degrees, minutes, and seconds, east or west from Greenwich. Since the distance from the equator to either pole is one fourth of the distance around the earth, their latitude is 90° north or south. As there are 360° in a circle any longitude more than 180° east becomes west. Therefore 180° is the limit of eastward or westward distance from Greenwich.

The north can be located, very nearly, at night by the North Star, and in the daytime by means of the sun at real noontime. This occurs when an object casts the shortest shadow. The North Star is located by means of the "pointers" of the "Dipper." Consult the references for details.

References: —

1. 1002: 27-28. The Geographical System.
2. 1304: 7. The Location of the North Star.
3. 1304: 402-405. Latitude and Longitude.
a. 1302: 13-14. Location of the North Star.

- b. 1303:8-11. Latitude and Longitude.
- c. 1305:297-299. Effect of Latitude on Climate.
- d. 1308:100-101. Effect of Latitude on Climate.
- e. 1310:311-313. Latitude and Longitude.
- f. 1312:24-28. Localization of Places, — Longitude and Latitude.

Experiment 23. — To Locate the North by Means of the Sun.

Apparatus: Straight stick, string.

a. Tie a stone to the string and use it as a plumb bob. Drive the stick into the ground so that it is vertical, using your plumb bob to test your work. At twenty minutes before noon begin marking where the end of the shadow falls. Repeat every three minutes until the shadow begins to lengthen. A line from the stick to the mark, which indicates the shortest shadow, points north. This shadow is cast at real noon. See Section 51, Time.

Experiment 24. — To Locate the South by Means of a Watch.

At any time of day point the hour hand of the watch at the sun. Halfway between the hour hand and the figure twelve, on the watch dial, is the south. Repeat at different times of day and satisfy yourself that this method is correct. Explain why this method is correct.

50. MOTIONS OF THE EARTH

The earth rotates on its axis once in about twenty-four hours, and revolves around the sun once a year. A point on the equator moves about one thousand miles an hour, while the whole earth moves around the sun at the rate of eighteen and five-tenths miles a second.

The proof that the earth revolves on its axis has been rather difficult, and would have been impossible, if it had not been for unlimited travel combined with scientific investigation. Since the poles are nearer the center of the earth, a body would weigh more at the poles than it does at the equator on account of universal gravitation. It has been computed that a body would weigh $\frac{1}{555}$ more at the poles than it would at the equator. It has been discovered, by experiment, that a body does weigh $\frac{1}{190}$ more at the poles than it does at the equator. This is the best proof that the world is in rotation. If you take a stone and tie it to a string and whirl it rapidly, the stone pulls on the string. In the same way a body at the equator, which is moving at the rate of nearly one thousand miles per hour, is thrown out from the earth with a force which resists the weight by $\frac{1}{289}$. Near the poles this rotation is very slow, just as the hub of a wheel revolves more slowly than the rim, and a body is not thrown out with the same force, that is, the force is $\frac{1}{289}$ less. Thus it is evident that the earth revolves, since $\frac{1}{190} - \frac{1}{555} = \frac{1}{289}$.

Revolution around the sun causes seasons. If the axis of the earth were not inclined to the plane in which it revolves around the sun, seasons would be unknown; but the axis of the earth is inclined $23\frac{1}{2}^{\circ}$ to what is called the plane of the earth's orbit. This axis always points in one direction — towards the North Star. Thus sometimes the north end of the earth is turned toward the sun; at other times the south end of the earth's axis is turned toward the sun. Therefore the sun apparently moves $23\frac{1}{2}^{\circ}$ north of the equator in the summer time, and $23\frac{1}{2}^{\circ}$ south of the equator in the winter time.

References: —

1. 1002: 147-152. Proofs of the Rotation of the Earth.
2. 1002: 168-172. Proofs of the Revolution of the Earth.

3. 1002 : 177-180.	The Seasons.
4. 1304 : 6-8.	Motions of the Earth.
a. 1001 : 47-50.	Effects of the Rotation of the Earth.
b. 1001 : 70-71.	The Earth's Orbit.
c. 1003 : 32-44.	The Revolution of the Earth round the Sun.
d. 1301 : 13-17.	Rotation, Revolution, and their Effects.
e. 1301 : 66-68.	Effects of Rotation and Revolution.
f. 1302 : 17-19.	Rotation and Revolution of the Earth.
g. 1303 : 6-7.	Rotation of the Earth and its Consequence.
h. 1305 : 43-44.	Motions of the Earth.
i. 1305 : 51-52.	Days, Nights, and Seasons.
j. 1307 : 18-19.	Effects of Rotation.
k. 1309 : 25-28.	Rotation and Revolution and their Effects.
l. 1310 : 308-311.	Rotation and Revolution of the Earth.
m. 1311 : 19-26.	The Year, Day, and Night.
n. 1312 : 19-24.	Revolution and Rotation and their Effects.

51. TIME

The motions of the earth furnish the natural divisions of time—day and night, and the year. One complete turning of the earth on its axis causes day and night, while the trip around the sun results in the march of the seasons. See Section 52 for a discussion of the seasons and their causes. The revolution of the moon around the earth gave us the month, until man discovered that the moon made more nearly thirteen than twelve trips per year. The week is an artificial division of time, and is not founded upon any natural cause.

Since the earth revolves 360° in twenty-four hours, it moves at the rate of 15° an hour. Therefore two places which are 15° apart, east and west, have a difference in time of one hour. This led to considerable trouble when railroads and the telegraph brought places nearer together, and Standard Time was devised to prevent misunderstandings.

The United States is divided into four time belts, each 15° wide, and each belt takes the time of its center meridian for all parts of the belt. This makes the maximum difference between standard time and local time one half an hour. Local time is not used except in astronomy.

References: —

1. 1002 : 226-242. Time.
2. 1304 : 404-405. Longitude and Time.
3. 1803 : 5. The Standard Unit of Time.
 - a. 1001 : 33-36. Different Kinds of Time.
 - b. 1001 : 36-41. Determination of Time.
 - c. 1003 : 48-55. Time.
 - d. 1309 : 28. Sidereal and Solar Days—Standard Time.
 - e. 1310 : 313-314. Longitude and Time.
 - f. 1311 : 26-27. Time.
 - g. 1312 : 30-32. The Day — Standard Time.

52. THE SEASONS

Every one is familiar with the change of seasons, although perhaps only a few have noticed the cause of the changes. The weather is warmer in summer than in winter for the same reason that there is a higher temperature at the equator than at any other place on the earth. The more nearly vertical the rays of the sun are, the more energy is received per square foot. To put it another way,—the more nearly the sun is overhead, the warmer it is, at the surface of the earth. The reason that the sun appears higher in the sky during the summer is because the axis of the earth is inclined $23\frac{1}{2}^{\circ}$ to its path around the sun. Since the north end of the axis always points in one direction,—to the North Star,—the sun seems to mount higher in the sky when the earth is in such a position that its axis points the north end in the general direction of

the sun. In winter time the north end of the axis is turned away from the sun, and the latter appears lower in the sky, or, in other words, in a very northern locality, the sun may not rise above the horizon.

References: —

1. 1002 : 177-180. The Cause of Seasons.
2. 1103 : 40-42. Temperature Changes during the Revolution of the Earth.
3. 1304 : 397-401. The Cause of Seasons Explained.
 - a. 1004 : 95-99. The Seasons.
 - b. 1302 : 19-22. The Change of Seasons.
 - c. 1303 : 46-49. Seasons and Zones.
 - d. 1305 : 52-53. The Seasons.
 - e. 1309 : 29-31. The Change of Seasons.
 - f. 1310 : 341-346. The Seasons.
 - g. 1311 : 20-26. The Motions of the Earth and the Seasons.
 - h. 1312 : 23-24. The Seasons.

Experiment 25. — The Seasons — Length of Day and Night.

Apparatus: A small globe.

a. Place the globe so that it receives light from a window, or from some artificial light at least ten feet distant. Turn the globe so that the north end of its axis points at right angles to an imaginary line drawn from the globe to the source of light. How much of the whole globe is illuminated? How much of the equator? How much of the sixtieth parallel of latitude?

b. Turn the axis of the globe so that it points in the general direction of the window. How much of the whole globe is illuminated? How much of the equator? How much of the thirtieth parallel? How much of the sixty-sixth parallel? Since the illuminated part indicates day, what is the length of day and night in each latitude? (Count the meridians of latitude.)

- c. Turn the globe so that the north end of the axis points away from the source of light and answer the same questions as in (b).
- d. What season is represented by (a), (b), and (c), respectively? Does the length of day vary at the equator?

53. THE CALENDAR

Upon the rotation and revolution of the earth is based our calendar, or record of time. There have been a great many changes in the calendar since man first tried to reckon time. Much has been discovered concerning the exact time of the rotation of the earth, and its revolution around the sun, and the calendar has been altered to meet known conditions. Time has been reckoned by the moon, but more generally by the seasons, and by day and night. The Julian Calendar, prepared by learned men at the direction of Julius Cæsar, was in force until 1582, when it was found to be ten days behind time. Pope Gregory caused this time to be dropped and the calendar brought up to date, and ordered that every fourth year should have an extra day. This was called the Gregorian Calendar. This calendar is not exactly correct, but by the method of omitting the leap year at the end of each century, except those centuries that are divisible by four hundred, the calendar will be nearly correct.

References: —

1. 1002 : 240-241. The Calendar.
2. 1304 : 7-8. Effects of Revolution and Rotation.
 - a. 1001 : 85-87. The Calendar.
 - b. 1003 : 133-136. The Calendar.
 - c. 1004 : 101-104. The Year and the Calendar
 - d. 1303 : 7-8. Day and Night : a Natural Unit of Time.
 - e. 1309 : 28-29. The Calendar and Time.
 - f. 1312 : 29-32. The Calendar and Time.

54. THE MOON

The nearest heavenly body, which arouses our curiosity more than other bodies on account of its apparent size, is our one satellite, the moon. It is quite probable that the moon was once part of the earth, while the crust of the earth was still very thin. Perhaps the earth was of irregular shape, and the moon was one of the large irregularities, and was thus thrown off, something like mud from the tire of a wheel. The moon shines by reflected light, and since the relation and position of the earth, moon, and sun are constantly changing, part of the moon is in shadow and part in light, and we see its different phases. The moon revolves around the earth every twenty-seven and one-third days, and also rotates on its axis in the same time. Thus we have never seen but one side of the moon.

The moon is now cold and has practically no water on it. Therefore it has no vegetation, and we have an example of a dead planet; for, in essential respects, the moon has every characteristic of a planet. The surface of the moon shows the result of vast volcanic action, which proves that the moon once was hot, but gradually lost all its heat.

References: —

1. 1002: 247-249. The Moon's Phases.
2. 1002: 251-254. Distance, Orbit, Rotation of the Moon.
3. 1002: 254-260. Size, Mass, Density, Atmosphere, of the Moon.
4. 1002: 264-268. General Surface Conditions of the Moon.
5. 1002: 271. Effects of Moon on the Earth.
 - a. 1001: 88. The Moon.
 - b. 1001: 93-94. The Moon's Distance.
 - c. 1001: 97-98. Diameter, Mass, Rotation, of the Moon.
 - d. 1001: 103-110. The Physical Characteristics of the Moon.

- e. 1003 : 112-132. The Moon, Tides, and Eclipses.
- f. 1004 : 117-125. Physical Characteristics of the Moon.
- g. 1306 : 13-15. The Moon, Tides, and Eclipses.

55. TIDES

The chief effect of the moon upon the earth is the production of tides in the ocean. The earth and the moon are attracted each by the other, but since the water is more mobile than the solid earth, the ocean piles up on the side nearest the moon and forms what is called high tides. These tides, out in the ocean, are about four feet above mean sea level. Near the shore tides may be much higher on account of the shape of the bays. Not only is there a high tide nearest the moon, but there is another on the side of the earth opposite to the moon, and in between these two tides are two low tides, on opposite sides of the earth. In a general way, the explanation is as follows: Since the water on the side of the earth farther away from the moon is not attracted as strongly as the earth is, the latter is pulled away from the water, leaving the water apparently high. The scientific explanation of tides belongs properly to advanced physics.

The sun also produces tides on the earth which are very slight compared with the moon's tides. However, if both the sun and the moon are on the same side, or opposite sides, of the earth, the result is that both act together to produce an extra high tide. These tides, which occur about twice a month, are called *spring tides*. If a line from the moon to the earth forms approximately a right angle with a line from the earth to the sun, the effect of the sun on the water is to reduce the moon tides slightly; these tides, which also occur about twice a month, are called *neap tides*.

References: —

1. 1002 : 220-221. Variation in the Tides.
2. 1304 : 187-189. Tides.
 - a. 1001 : 187-198. Tides and their Effects.
 - b. 1301 : 210-214. The Tides and their Causes.
 - c. 1303 : 124-126. The Cause of Tides.
 - d. 1305 : 125-134. Tides, their Causes and Variations.
 - e. 1306 : 192-203. Tides.
 - f. 1307 : 201-204. Tides.
 - g. 1308 : 10-15. Tides and Tidal Currents.
 - h. 1309 : 183-192. Tides.
 - i. 1311 : 290-295. Tides and their Causes.
 - j. 1312 : 181-184. Tides, Tidal Waves, and their Causes.
 - k. 1313 : 111-113. Tides.

56. METEORS

These are very small bodies of matter, or combinations of small bodies, revolving around the sun like the planets. They are cold, and not large enough to reflect sufficient light to be seen, and therefore they are invisible until they suddenly flash into our atmosphere. The light is produced by the intense heat due to friction against our atmosphere. The large majority of meteors are entirely consumed, or dissipated into dust, before they reach the earth. A huge number of meteors fall every year, and it has been estimated that they add about forty thousand tons of weight to the earth each year. As they fall to the earth they move at about twenty-six miles a second, and their fall may be accompanied by a roaring noise and often ends in an explosion. Their composition is mostly stone, although some have been found composed practically of pure iron.

References: —

1. 1002 : 374-381. Meteors and Meteorites.
2. 1002 : 384-385. Theories Respecting Origin of Meteorites.

- a. 1001 : 289-299. Meteors and Shooting Stars.
- b. 1003 : 187-190. Meteors and Meteoric Showers.
- c. 1004 : 279-283. Meteors and Shooting Stars.
- d. 1004 : 283. Light, Heat, and Origin of Meteors and Shooting Stars.
- e. 1004 : 290-293. The Connection between Comets and Meteors.
- f. 1303 : 23. Meteors or "Falling Stars."
- g. 1305 : 37-38. Meteors and Comets.
- h. 1306 : 15-17. Comets, Shooting Stars, and Meteors.
- i. 1310 : 324-325. Height of Atmosphere Shown by Meteors.
- j. 1312 : 10. Meteors and Shooting Stars.

57. COMETS

Comets are composed of a head or nucleus, and a tail which varies in length, increasing as the comet approaches the sun. The volume of a comet is extremely large, almost passing human comprehension. Yet the mass is very slight, and in the largest comet is only a small fraction of the earth's mass. The light of a comet is due partly to light reflected from the sun, and partly to some electrical disturbance which is not well understood. They are composed, doubtless, of large aggregations of very small meteors acting as one large body. It is probable that if the earth were struck by a comet, the shock of collision would be very slight and little damage would be done.

References: —

- 1. 1002 : 356-371. Comets and Meteors.
- 2. 1002 : 381. Connection between Comets and Meteors.
 - a. 1001 : 264-289. Comets.
 - b. 1001 : 381. Danger from Comets.
 - c. 1001 : 299-302. The Connection between Comets and Meteors.

- d. 1003: 176-180. Comets and Meteors.
- e. 1003: 185-187. Constitution of Comets.
- f. 1004: 261-266. Mass and Density of Comets.
- g. 1004: 267-271. The Tails of Comets.
- h. 1004: 271. Nature of Comets and Danger from Comets.
- i. 1004: 290-293. Relation between Comets and Meteors.
- j. 1305: 37. Comets.
- k. 1312: 8-10. Comets.

58. THE STARS

Only an estimate can be made in regard to the number of stars, but approximately five thousand are visible to the naked eye, while probably more than one hundred million can be identified with the modern astronomical instruments. We must remember, too, that all the stars are suns, and that it is quite likely that some suns have their planets revolving around them, which are too small to be seen.

References: —

- 1. 1002: 52. The Number of Stars.
- 2. 1304: 3-4. Other Spheres.
- a. 1001: 303-304. The Number of Stars.
- b. 1001: 341. Planetary System Attending Stars.
- c. 1003: 191-192. About Stars in General.
- d. 1004: 294-295. Number of Stars.
- e. 1004: 310-311. Dimensions of the Stars.
- f. 1301: 25-27. The Universe.
- g. 1302: 13-14. The Starry Heavens.
- h. 1303: 14. The Stars Resemble the Sun.
- i. 1305: 35. Fixed Stars and Planets.
- j. 1306: 17-18. The Stellar System.
- k. 1309: 14. The Sun is also a Star.

59. DISTANCES OF THE STARS

The stars are so distant that we must make use of a unit of measurement other than the mile. It would be hard to express these distances in miles, and the numbers would be meaningless. Light travels one hundred and eighty-six thousand miles a second. The unit of distance is taken as the space through which light would pass in one year, which is called the *light-year*. Using this standard of measurement, the nearest star is about three light-years away. Those stars which are just visible to the naked eye are between two hundred and three hundred light years distant. The telescopic stars, that is, those stars which can be seen only through the telescope, are so distant that the light from them has been thousands of years on its way to us. When we see some change in a star, or group of stars, we are seeing something which happened several hundreds of years ago.

References: —

1. 1002: 504-507. Distances of the Stars.
2. 1803: 390. Results of the Finite Speed of Light.
 - a. 1001: 315. The Unit of Stellar Distance.
 - b. 1003: 209-212. Distances of the Stars.
 - c. 1004: 304-306. Distance of the Stars — The Light-Year.
 - d. 1301: 27. Distances of the Stars.
 - e. 1303: 12. Distances of the Stars.

60. THE EARTH AS A WHOLE

The surface of the earth is a solid mass of rock, of which only a very thin top layer has been changed to soil and sand. Thus the surface is covered in most places, except where the rocks show through, with a mixture of material ranging in

size and bulk from boulders to clay. The interior of the earth is probably solid rock, although hot enough to be liquid, if it were not for the pressure upon it.

References: —

1. 1002 : 114-119. Shape of the Earth.
2. 1002 : 129-130. Density of the Earth.
3. 1103 : 21-23. Relation of the Earth to the Sun.
4. 1304 : 13-28.
 - a. 1001 : 45. General Features of the Earth.
 - b. 1004 : 78-88. General Features of the Earth.
 - c. 1302 : 26-29. Structure of the Earth.
 - d. 1302 : 29-33. The Earth's Crust — Mantle Rock.
 - e. 1303 : 15-17. Structure and Temperature of Earth.
 - f. 1305 : 41-42. Internal Condition of the Earth.
 - g. 1309 : 18-22. Shape, Size, and Density of the Earth.
 - h. 1310 : 307-308. Form of the Earth.
 - i. 1311 : 1-12. Changes on the Earth.
 - j. 1312 : 16-19. Shape, Size, and Structure of the Earth.

61. THE EARTH AS A MAGNET

The ordinary magnet is a piece of hardened steel, which, having been rubbed by another magnet, or influenced by an electric current, is capable of attracting pieces of iron or steel. If we suspend such a magnet by a fine thread, or on a delicate pivot, we will find that it takes a definite direction, the ends pointing north and south. This is due to the magnetism of the earth.

The points toward which the needle directs itself are called the magnetic north and south poles, but they do not lie at the geographical north and south poles. Thus, if we go east or west, there will be a decrease or increase in the variation between the true north and the north which is indicated by the

magnetic needle. This variation is not always constant, as the magnetic poles swing backward and forward.

The cause of the earth's magnetism is not fully understood, but it is probably due to the energy which the earth receives from the sun. If there is any disturbance of the sun, as when sun spots appear, there is always a disturbance of all the magnetic needles on the earth. Under these conditions the needles act as if the magnetic poles were swinging hundreds of miles.

References: —

1. 1002: 437-438. A Theory of the Earth's Magnetism.
2. 1304: 418-419. Magnetism.
3. 1803: 235-237. Terrestrial Magnetism.
 - a. 1303: 17-18. The Earth as a Magnet.
 - b. 1305: 30-33. The Earth a Huge Magnet.
 - c. 1306: 29-30. Magnetism and Electricity.
 - d. 1307: 274-279. The Aurora and the Earth's Magnetism.
 - e. 1307: 279. Magnetic Storms.
 - f. 1309: 33-39. The Earth as a Magnet and Magnetic Storms.
- g. 1310: 301-305. Terrestrial Magnetism.
- h. 1311: 274-278. The Earth's Magnetism.
- i. 1312: 33. The Earth as a Magnet.
- j. 1809: 367-369. Terrestrial Magnetism.
- k. 1810: 245-246. The Earth a Magnet.

Experiment 26. — The Earth's Magnetism.

Apparatus: Bar magnet, pieces of steel, clock spring at least 3" long, wooden support, very fine silk thread, or untwisted fiber.

a. Support a piece of clock spring at its middle point by a thread at least 12" long, and slowly bring one end of the magnet near it. Do not touch the piece of clock spring with the magnet. If you happen to, ask for another piece. Approach the

other end of the magnet to the clock spring. You should not see any difference in the result.

b. Touch one end of the clock spring to one end of the magnet, and then touch the other end of the clock spring to the other end of the magnet. This magnetizes the clock spring. Support the clock spring as before, and repeat (*a*). Do this several times and make a complete statement of your observations.

c. Remove all magnets and iron from near the clock spring and it will take a definite direction due to the earth's magnetism. How does this compare with the direction of the true north?

62. OTHER MAGNETS

Besides the earth, there are other magnets, some natural and some which are made by man. A certain ore of iron, called *magnetite*, on account of its peculiarity, has a weak attraction for iron and steel. Suitable pieces of this ore are sometimes mounted with iron ends, and are capable of holding up a mass of iron which is equal to their own weight. Powerful magnets are made from steel bars which have received their magnetism through the agency of electricity. If a wire covered with cotton, silk, or some other material through which electricity does not readily pass, is wound around a piece of iron, and a current of electricity allowed to pass through the wire, the iron will become a strong magnet, attracting other pieces of iron and steel with considerable force. As soon as the electricity ceases to pass through the wire around the iron, the iron loses its magnetism. If, on the other hand, a similar electric current is passed around steel, the magnetism remains in the steel, after the electric current has been discontinued. Therefore a steel magnet is called *permanent*.

The reason that electricity produces magnetism in a piece of iron is because there is magnetism around every wire carrying an electric current. Magnetism is induced in the iron. This effect is made use of in the electromagnet, bell, telephone, telegraph, motor, and dynamo, as well as in many toys.

References: —

1. 1803 : 227-234. Magnetism.
2. 1803 : 261-262. Electricity in Motion Produces Magnetism.
 - a. 1801 : 300-310. Magnetism.
 - b. 1802 : 368-378. Magnetic Effect of the Electric Current.
 - c. 1804 : 523-530. Magnetism.
 - d. 1805 : 369-380. Magnetism.
 - e. 1806 : 429-439. Magnetism.
 - f. 1807 : 339-352. Magnetism.
 - g. 1808 : 248-264. Magnetism.
 - h. 1809 : 359-373. Magnetism.

Experiment 27. — Magnetism.

Apparatus: Two bar magnets six inches long, piece of quarter-inch iron rod (large nail), thirty feet of double cotton-covered copper wire No. 20, dry cell, bits of wood, brass, iron nail, silk thread.

a. Suspend one magnet at its middle point by a silk thread, and balance it. If the thread is allowed to untwist, the magnet may point to the north. Approach in succession the two ends of the other magnet. The similar poles are marked. Write out the laws of attraction and repulsion. Do the magnets have to obey these laws?

b. Wind about thirty feet of insulated wire on the large nail, trying to imitate the winding of thread upon a spool. Note that there is no magnetism in the iron. Attach the two ends of the wire to the connecting screws of the dry cell. Can

the electromagnet pick up iron now? Can it pick up anything except iron and steel? Disconnect the dry cell. Is the nail a magnet now? Note: Do not leave dry cell attached to magnet for more than a few seconds at a time, or the dry cell will be spoiled.

c. Approach the electromagnet to the suspended magnet. Has it two poles? Change the connection of the dry cell and test the electromagnet by the suspended magnet. What has happened? Electricity is reversible, and magnetism likewise.

63. THE NORTHERN LIGHTS

At night in the far north the northern sky is often illuminated with beautiful fluttering streamers of colored light which now grow brighter, now dimmer; often changing in color, they are ever glorious. At the same time that these wonderful displays take place, the magnetic needles quiver and jump, showing that there is some connection between the Northern Lights and the earth's magnetism. A theory which is rapidly gaining in favor with scientists is that the magnetism of the earth and the Northern Lights both owe their origin to the electrical energy which the earth is receiving from the sun. Since sun spots influence the magnetic needle, the relation seems to be reasonable. Electrical discharges through rarefied gases produce, in a small way, the same color effects as are manifested in the Northern Lights.

References: —

1. 1002: 139. The Aurora.
2. 1103: 175-176. The Aurora and its Cause.
3. 1304: 419. The Aurora Borealis and Australis.
 - a. 1102: 270-271. The Aurora Borealis.
 - b. 1303: 18-19. The Aurora.

- c. 1305 : 108. The Aurora.
- d. 1309 : 277-278. The Aurora and its Cause.
- e. 1312 : 396-397. The Aurora and its Cause.
- f. 1801 : 336. The Aurora.

64. SOURCES OF ELECTRICITY

There are three sources of electricity — frictional, chemical, and magnetic. The quantity of electricity produced by friction is very small. Whenever one substance is rubbed by another, electricity results and may be easily detected. Two pieces of lump sugar, if rubbed together in a dark place, will give out slight flashes of light. It is possible to obtain an electric spark from a cat, by rubbing its back and then touching its nose or ear. Put the cat on an insulated chair, that is, have plates of glass under the legs of the chair.

Whenever two dissimilar elements are placed in a suitable solution, and their ends joined, a current of electricity passes which varies in strength according to the elements and the solution. Such a combination is called a *galvanic cell*, and modifications of these cells are used largely for electric bells and gas ignition.

By far the greatest amount of electricity is produced by moving a wire near a magnet. If such a wire has its ends joined, a current of electricity will pass through it. The cause for this production of electricity is not known. The dynamo is the practical application of this principle.

References: —

1. 1103 : 175-179. Atmospheric Electricity.
2. 1803 : 238-239. Development of Electrification by Friction.
3. 1803 : 262-263. The Galvanic Cell.
4. 1803 : 282-283. The Theory of the Simple Cell.

5. 1803 : 312. The Principle of the Dynamo.
a. 1801 : 312-314. Electrification by Friction.
b. 1801 : 337-340. The Simple Voltaic Cell.
c. 1801 : 378-381. Electromagnetic Induction.
d. 1804 : 434-435. Electrification.
e. 1804 : 465-468. Voltaic Cell.
f. 1805 : 380-391. The Simple Voltaic Cell.
g. 1805 : 430-437. The Electric Dynamo.
h. 1806 : 481-484. Electrification by Friction.
i. 1806 : 501-502. Electricity Developed by Chemical Action.
j. 1807 : 353-356. Voltaic Cell.
k. 1807 : 389-404. Electromagnetic Induction.
l. 1808 : 293-294. The Electric Current.

Experiment 28. — Sources of Electricity.

Apparatus: Pith ball on stand, rubber rod, dry cell, strips of zinc and copper, or carbon, glass tumbler, magnetic needle, six-inch magnet, fifty feet insulated copper wire No. 20.

Materials: Dilute sulphuric acid (one part acid to nine parts water).

- a. Bring the rubber rod near the pith ball. Nothing happens. Dry the rod, rub it, and bring it near the pith ball. What happens? Let the pith ball touch the rubber rod and again approach the rubber rod. Tell what happens, and give the laws of electric charges. Note: When the pith ball touched the rod, it became charged with the same kind of electricity. Before being touched, it had induced in it the opposite kind of electricity.

b. Wind ten feet of insulated wire around the compass in a thin coil, piling some of the windings upon others. This makes a galvanometer, and to use it the coils should run north and south. Attach the dry cell and note how the needle turns. Reverse the connections and see in which direction the needle turns. Take as your guide that the electricity comes from the

carbon of the dry cell and returns to the cell through the zinc. The carbon is called positive, +, and the zinc negative, -.

c. Take a strip of copper and one of zinc. Attach them by wires to your galvanometer and place them in a glass tumbler. Pour in a little of the dilute solution, watching the needle of the compass. What happens? In what direction does the needle turn? Which is +, copper or zinc? The current soon decreases on account of chemical changes taking place within the solution and because the bubbles of hydrogen, which are set free, offer resistance to the flow of the current. Shake the copper strip, and watch the needle.

d. Wind forty feet of wire around the magnet, in a close coil, after first winding the magnet with twenty turns of paper. Remove the coil and pull out the paper. Attach the coil to the galvanometer by means of wires which are at least six feet long. Now, watching the needle, push one end of the magnet into the coil. Note deflection of needle. Which way did the current go? Where did the electricity come from? Again watching needle, remove the magnet. Conclusions? Repeat with the other end of the magnet. Conclusions?

65. APPLICATIONS OF ELECTRICITY

In this section we shall take up only those applications of electricity which include magnetism. In Sections 66 and 67 other applications will be studied.

Since the magnetism by electricity lasts only while the source of current is connected with the magnetizing coils, we can regulate or stop and start the magnetism at will. The electric bell is the simplest example. The electromagnet pulls the hammer against the bell, but when the hammer is nearly there, the current is broken by means of the spring

connection on part of the hammer, and the latter flies back only to connect the electricity and be attracted again. This continues as long as the supply of electricity lasts.

The electric motor consists of two magnets, one stationary and the other free to move on an axis. The unlike poles attract each other, but the electricity is shut off, or turned into other coils of the moving magnet, just before it comes into a position of equilibrium, and the motion continues.

The telegraph is nothing but an electromagnet and a movable piece of iron, which is attracted when the current passes, and is pulled away from the magnet by a spring, when the current ceases to flow.

If a coil of wire is revolved in a place where there is magnetism, electricity is produced. This is made use of for the production of electricity in large quantities. The more electricity produced, the harder it is to move the coil of wire. A machine for this purpose is called a *dynamo*, and resembles an electric motor.

The telephone is a very useful application of electricity, and the student should consult the references for a fuller consideration of it, as well as for details concerning all of the applications of electricity.

References: —

1. 1803 : 312-342. The Dynamo, Motor, and Magnetic Induction.
- a. 1801 : 391-392. The Dynamo-Electric Machine.
- b. 1804 : 595-606. The Telegraph and the Telephone.
- c. 1805 : 401-404. Electric Bell and the Telegraph.
- d. 1807 : 365-369. Electric Bell and Telegraph.
- e. 1808 : 353-363. Electric Bell, Telegraph, and Telephone.
- f. 1809 : 436-445. Electric Bell, Telegraph, and Telephone.
- g. 1810 : 288-300. The Telegraph and Electromagnetic Induction.
- h. 1811 : 280-291. The Electromagnet, Telegraph, and Bell.

Experiment 29. — The Electric Bell, Telegraph, and Telephone.

Apparatus: Galvanometer which was made in Experiment 28, large nail, smaller nail, fifty feet No. 20 insulated copper wire, dry cell, steel magnet and coil which was made in Experiment 28.

a. Wind nearly all of the wire upon the large nail in smooth layers; fasten one end of the wire to the small nail, taking care that the bare copper comes into contact with it; fasten the other end to one of the dry cell terminals, and connect a wire to the other terminal of the dry cell. When this wire is touched to the small nail, it is attracted to the large nail. If care is used, the small nail may be made to vibrate very rapidly. When a single tap is made by the small nail, the telegraph is illustrated; if the small nail vibrates, we have a simple electric buzzer, which would ring a bell if the latter were properly placed.

b. Attach the ends of the coil, in which the steel magnet lies, to the galvanometer, with wires which are at least six feet long. Bring a piece of iron (the nail) up to the magnet, and note the deflection. Pull the iron away and note the deflection. The motions must be rapid. What do you conclude? This illustrates the simple telephone. When the voice strikes the iron plate of a receiver used as a transmitter, it is made to vibrate, and currents are caused to flow in the wire around the magnet in the back of the iron plate. These currents affect a similar plate in the other receiver, and it makes the same movements as does the first iron plate.

66. CHEMICAL EFFECTS OF ELECTRICITY

Electricity, when passing through a chemical solution, tends to separate the chemicals into their components. Thus water is separated into two volumes of hydrogen and one

volume of oxygen. A solution which contains copper is separated into copper and the other constituents, thus making copper plating possible. Nearly all of the metals may be used for electroplating, and they may be purified by this method. The electric energy may be utilized to produce certain forms of chemicals, and then the chemicals may be used later to produce electricity. This fact is made use of in the storage cell. The lead cell consists of two lead plates which are immersed in dilute sulphuric acid. The plate attached to the + terminal becomes coated with lead peroxide, while the other plate becomes freed from all oxygen and is practically pure lead. The lead plates now act as if they were different elements and produce electricity similarly to a rod of zinc and a rod of carbon in dilute acid. The Edison cell uses nickel and iron for the plates.

References : —

1. 1601 : 123. The Electrical Sources of Soil Nitrogen.
2. 1703 : 38-39. The Electrolysis of Water.
3. 1703 : 329-330. The Explanation of Electrolysis.
4. 1803 : 292-298. Chemical Effects of Electricity.
 - a. 1701 : 366. Electroplating.
 - b. 1801 : 349-354. Electrochemical Effects.
 - c. 1804 : 474-478. Chemical Effects of the Electric Current.
 - d. 1804 : 593-595. Electrotyping.
 - e. 1807 : 407-411. Chemical Effects of Currents.
 - f. 1809 : 400-401. The Storage Cell.

Experiment 30. — Electroplating.

Apparatus : Two dry cells with carbon of one connected with zinc of the other, or one storage cell, beaker 250 c.c., strips of copper, 1" \times 5", connecting wires, German silver wire No. 22.

Materials : Copper sulphate, paraffin, sandpaper, nitric acid, 10 per cent, benzine.

a. Fill the beaker with a saturated solution of copper sulphate, attach one copper strip by a wire to the positive terminal of the source of electricity, and insert it in the solution. Sandpaper the other copper strip and dip it into melted paraffin. When the paraffin becomes set, scratch your initials, or make some design, in the wax, taking care to cut into the copper. Dip the strip in 10 per cent nitric acid, and then put it immediately into the copper sulphate solution. Connect it with the negative terminal of the source of electricity, using some of the German silver wire. The latter regulates the flow of electricity on account of its high resistance. If bubbles collect on the engraving, too much current is passing, and more German silver should be added to the circuit. In half an hour the initials should be raised enough to be visible. Melt off the wax, and clean with benzine. If the strip of copper is heated, it will become oxidized, and then if the engraving or raised letters are sandpapered, they will stand out in contrast.

Experiment 31. — The Storage Cell.

Apparatus : Three dry cells, electric bell, two strips of lead $1'' \times 5''$, beaker 250 c.c., wires.

Materials : Dilute sulphuric acid 10 per cent.

a. Connect the three dry cells in series, carbon of one cell with zinc of the next cell, and connect the free ends to the two lead strips. Place the strips in the beaker so that they do not touch, and fill the beaker nearly full of dilute sulphuric acid. Allow the current to pass for two or three minutes. Note the bubbles. They are hydrogen and oxygen. Disconnect wires from dry cell, and connect them to the bell. It should ring for a few seconds. Why does the bell stop ringing? Charge the storage cell again, but in the opposite direc-

tion. Again use the stored energy to ring the bell. Repeat several times, each time reversing the charging. Does the bell ring longer? Examine the lead plates and give a reason.

67. HEAT AND LIGHT FROM ELECTRICITY

Whenever electricity passes through a substance, it meets with more or less resistance, according to the material. Whenever there is resistance, heat is produced. The incandescent lamp is an example of heat, as well as light, being produced by electricity. Very often fires have been caused by overheated electric wires. In nearly every circuit, however, there is inserted a piece of wire of low melting point, which melts when an excessive current passes, and thus protects the rest of the circuit.

References: —

1. 1803 : 305-311. Heat and Light from Electricity.
 - a. 1801 : 400-403. The Electric Light.
 - b. 1804 : 587-593. The Electric Light.
 - c. 1805 : 456-462. Heat Effects of Electricity.
 - d. 1807 : 385-388. Heat, Light, and Power from Electric Currents.
 - e. 1808 : 305-306. Heating Effects of the Electric Current.
 - f. 1808 : 363-365. Electric Lighting.
 - g. 1809 : 445-451. Heat and Light from Electricity.
 - h. 1811 : 317-318. The Incandescent Lamp and the Arc Light.

Experiment 32. — Heat and Light from Electricity.

Apparatus: Two or three dry cells, or a storage cell, German silver wire No. 30, iron wire No. 30, file.

a. Connect the cells in series and pass the current through an inch of the fine wire. Note the rapidly increasing temperature and the light which is produced. Iron melts at about 2200° Fahrenheit. What do you think about the pro-

duction of heat by electricity? Red-hot temperature is about 950° Fahrenheit.

- b. Attach one wire from the three cells to a file, and rub the other wire on it. What do you see?
- c. If there is electric power in the building, the teacher may show these effects to a startling degree.

68. HEAT PRODUCES LIGHT

We learned in Section 2 that heat is due to the motions of the molecules, and in Section 3 that if the molecular motion becomes rapid enough, the substance changes from a solid to a liquid and then to a gas. These changes concern the material alone. There is another effect which is produced by the rapidly moving molecules, and we call the visible result *light*.

All space between all bodies, and between the molecules of every substance, is filled with what is usually called *ether*, and sometimes *light-bearing ether*, to distinguish it from the anæsthetic. When the motions of the molecules are rapid enough, waves similar to but very much smaller than water waves are set up in this ether. All these waves of the ether are electric waves, few of which affect the eye, but all of which transmit energy. Since one form of energy can be changed into all other forms, we obtain heat, light, and chemical effects from the sun.

If a piece of metal is gradually heated, it begins to glow at about 950° Fahrenheit, 525° Centigrade, and increases in brightness up to dazzling white at about 2200° Fahrenheit, 1200° Centigrade. This is true only if the metal does not turn into a gas. A very good example is the tungsten incandescent lamp, for metals, and the ordinary incandescent lamp, for carbon.

References:—

1. 1002: 399-403. The Production of Light — the Electron.
2. 1304: 234. Heat and Light.
3. 1601: 12-13. Heat Produces Light.
4. 1710: 46-47. Heat Produces Light.
5. 1803: 463-464. Radiation and Absorption.
 - a. 1804: 317. Molecular Motion Produces Light.
 - b. 1805: 215. Heat a Source of Light.
 - c. 1807: 257-258. Heat Produces Light.
 - d. 1809: 274. Heat Produces Light.
 - e. 1811: 220-222. Natural and Artificial Sources of Light.

Experiment 33. — Heat Produces Light.

Review the heating and lighting effect of the electric current. Regulate the amount of current which passes through an incandescent lamp by means of a long piece of German silver wire of small diameter. The same plan may be used in connection with a small piece of iron wire and the dry cells.

69. LIGHT AND VISION

While existence requires heat and food and air, vision, as we understand it, could not exist without light, and life would be very empty. We must consider that light is due to electric waves sent out by a body, which, by virtue of temperature, or chemical change, can produce these wave motions. When these waves strike the eye, we receive the sensation of light, and while the waves would be there, just the same, whether they struck the eye or not, they would not produce the same result. It may practically be said that if there is not an eye to see, there is no light. Those particular waves which produce the sensation of light in the eye do not produce other effects to any extent, for the heat effect and the chemical effects which we receive are due to waves of a different

length. There are however, some heat and some chemical effects produced by all of the waves.

All objects, except those which produce light, are seen on account of light which they reflect. (See next section.) If there is no light to be reflected, the objects must become invisible. No animal can see in complete darkness, although some animals can see in very dim light. Section 78 describes a method of light measurement. Vision is treated in Section 199.

References: —

1. 1002 : 398-399. The Nature of Light.
2. 1304 : 232. Light.
3. 1803 : 404-405. The Nature of Light.
4. 1803 : 409. The Sources of Light Waves.
 - a. 1801 : 188-190. Light — Speed of Light.
 - b. 1802 : 202-204. Theories of Light.
 - c. 1804 : 318-319. Light Defined.
 - d. 1805 : 213-214. Nature of Light.
 - e. 1806 : 138-140. Nature of Light.
 - f. 1807 : 255-257. Nature and Transmission of Light.
 - g. 1808 : 373-374. Nature of Light.

70. REFLECTION

When light strikes against a smooth, bright surface, it is bent back and is said to be reflected. In this case there is very little absorption, and nearly all the energy is returned. The angle at which the light leaves such a reflecting surface is equal to the angle at which the light strikes it. We say that the *angle of reflection* is equal to the *angle of incidence*. Light-colored materials reflect more light than the darker shades, and smooth surfaces, especially polished metallic surfaces, reflect the most. The absorption in an ordinary mirror is about 10 per cent.

References: —

1. 1103 : 168-169. Reflection of Light.
2. 1304 : 235-236. Reflection and Absorption.
3. 1803 : 416-419.
 - a. 1305 : 102-103. The Mirage.
 - b. 1801 : 196-197. Reflection.
 - c. 1802 : 212-217. Reflection of Light.
 - d. 1804 : 331. Reflection of Light.
 - e. 1805 : 225-227. Reflection.
 - f. 1806 : 150-151. Reflection.
 - g. 1807 : 268-269. Reflection of Light.
 - h. 1808 : 382-383. Reflection.
 - i. 1809 : 283-288. Reflection at Plane Surfaces.

Experiment 34. — Reflection.

Apparatus: Piece of mirror glass 5" \times 2" with a transverse scratch at its middle point, block of wood 5" \times 2", two elastic bands, pins, protractor.

Materials: Sheet of note paper.

- a. Draw a straight line across the paper and place the mirror, attached to the block of wood by means of the elastic bands, so that the silvered surface lies along the line. Slip the protractor under the edge of the mirror so that its diameter is also on the line, with its middle point under the scratch. Mark every 5° on the paper, at the edge of the protractor, numbering from zero, at the middle mark, to ninety at each end of the diameter.

b. Stick a pin at the 5° mark and look for its reflection in the mirror. Stick another pin, near the protractor, in line with the reflection and the center mark. Where is the last pin?

c. Make several trials, sticking the first pin in different places. Are you satisfied with your results? Tabulate them.

71. COLOR

It is customary to speak of the color of objects, as if color existed. There is really no such a thing as color, except as a sensation. Colors are not due to materials, as such, but to the fact that some materials are capable of absorbing part of the light and reflecting the rest. White light is made up of all the colors of the rainbow. (See next section.) Accordingly, if we look at some material which absorbs all colors except red, it will appear red. This is because it reflects the red light, or, more scientifically, it reflects those particular wave lengths which give to our eye the sensation of red. The same explanation applies to all other colors. If, on the other hand, we use some source of light which does not produce pure white light, objects do not appear the same by it as by sunlight. This is because some of the waves which the object can reflect are not present, and therefore cannot be reflected.

The color of the sky is due to the fact that the light is partially blocked by small particles of dust in the air; those particular wave lengths which gives us the sensation of blue are blocked most, and are thus either stopped or reflected. Except in the neighborhood of the sun, the light which illuminates the sky is due to light which has struck the earth and has been reflected up to the sky. Most of the light which has been reflected from the earth passes on into space, but those very short wave lengths which give us the sensation of blue are reflected back by the particles of the air, and we see the sky as blue. The fact is, the sky is absolutely black; that is, it has no color whatsoever. In those countries where there are no manufactories, and where the air is extraordinarily clear, the sky is very dark blue; and balloonists tell us that the

farther they ascend into the air, the darker the sky becomes. If the air were absolutely pure, we would have a black sky.

References: —

1. 1103 : 170-171. Colors of the Sky.
2. 1304 : 233. The Cause of Colors.
3. 1601 : 7. Color.
4. 1803 : 443-450.
 - a. 1305 : 103-105. Color of the Atmosphere.
 - b. 1801 : 238-241. Color.
 - c. 1802 : 258-260. Color — Color Sensation.
 - d. 1804 : 386-391. Color.
 - e. 1805 : 244-247. Color.
 - f. 1807 : 322-332. Dispersion and Color.
 - g. 1808 : 418-421. Color.
 - h. 1811 : 214-220. Cause of Color.

Experiment 35. — Color.

Apparatus: Alcohol or gas lamp, asbestos paper to fit lamp as a collar, pieces of cloth colored red, yellow, and blue, beaker 250 c.c.

Materials: Common salt, soap, solution of rosin in alcohol, (one part rosin, ten parts alcohol).

a. Dip asbestos paper in saturated solution of salt, and fasten around burner. Then light burner and darken room. Hold the piece of cloth near the flame. What color is the red now? The yellow? The blue? Conclusions? Notice the color of the faces of your companions. Are the faces rosy? Does color belong to an object itself?

b. Fill beaker with water, and add a drop or two of the rosin solution. The rosin is insoluble in water and is suspended in very fine particles. What color is the water by reflected light? By light which has passed through the water, that is, transmitted light? Add more rosin and state results. What is the connection between this experiment and the color of the sky?

72. REFRACTION AND DISPERSION

If a beam of white light is allowed to pass through a triangular piece of glass, or other transparent medium, it is not only bent towards the thicker side of the *prism*, as a piece of glass so shaped is called, but it is also separated into the seven primary colors,—red, orange, yellow, green, blue, violet, and indigo. These colors are called the *prismatic* colors, since they are produced by means of a prism. The bending of the path of light is called *refraction*; the separation into the component color is called *dispersion*.

The gorgeous colors of sunrise and sunset are caused by drops of water in the atmosphere breaking up the white light of the sun into the primary colors. Some of these colors are scattered or bent so that they do not reach the eye. We then receive the sensation which is due to the other colors. In a cloudless sky, with a very small amount of fog or haze, there will be no colors in the sunset or the sunrise.

References:—

1. 1002 : 142-143. Refraction of Light by the Atmosphere.
2. 1103 : 166-168. Refraction of Light.
3. 1103 : 169. Diffraction of Light.
4. 1304 : 232-233. Color Effects.
5. 1803 : 398-399. Refraction.
 - a. 1801 : 211-142. Refraction.
 - b. 1801 : 230-231. Dispersion.
 - c. 1802 : 226-228. Refraction.
 - d. 1802 : 252. Dispersion.
 - e. 1804 : 346-348. Refraction.
 - f. 1804 : 368-370. Dispersion.
 - g. 1805 : 227-232. Refraction.
 - h. 1805 : 238-239. Dispersion.
 - i. 1806 : 171-175. Refraction.

Experiment 36. — Refraction and Dispersion.

Apparatus: Triangular glass prism 60° , one-inch face, three inches long.

a. Place prism on its end, on piece of note paper, and draw pencil line around it. Now draw a straight line, three inches long, up to one face of the prism at an angle of about 45° . Looking through that side of the prism through which the line would come out, if continued, lay a rule in line with the pencil line *as seen through the prism*. Draw a line along the rule, remove the prism and connect the ends of the two long lines by means of a short one across the outline of the prism. The complete broken line indicates the path of light through the prism. Which way is it bent?

b. Go near a window, and pull down the curtain so that only a narrow beam of sunlight enters the room. Hold the prism in this beam until you see the prismatic colors. Which color is bent the most? How many colors can you distinguish? Name them.

73. THE RAINBOW

The rainbow is well named, as it is composed of raindrops which occupy positions in the arc of a circle. A rainbow has no existence; that is, it is a condition, and raindrops which are in the proper position at one instant pass out of that position the next instant, to have their places occupied by other raindrops.

Each drop of water which takes part in the production of a rainbow acts similarly to the prism in Experiment 36. All combined, they give the impression of bands of colors. Every drop of water which sends a certain kind of waves to the eye is at an equal distance from the eye. Now all points which

are equidistant from a given point lie on the arc of a circle. That is why a rainbow is curved.

References : —

1. 1103 : 174-175. The Rainbow.
2. 1803 : 452-454. The Rainbow.
- a. 1801 : 232-235. The Rainbow and its Cause.
- b. 1802 : 254. The Rainbow.
- c. 1804 : 370-371. The Rainbow.
- d. 1805 : 241-244. The Rainbow and its Cause.
- e. 1807 : 335-337. The Rainbow.
- f. 1808 : 415-418. The Rainbow.
- g. 1809 : 324-325. Action of a Raindrop on Sunlight, — the Rainbow.

Experiment 37. — The Rainbow.

Apparatus : Piece of glass 3" × 3", medicine dropper.

Materials : Lubricating oil.

- a. Rub a very little lubricating oil on one surface of the glass plate and place a drop of water on it, using the medicine dropper. The drop must be small enough to be nearly spherical. Place the plate in the sun and move the head until, in one position or another, all the colors of the rainbow have been seen. Why is the oil used? Why should a small drop be used?

74. DIFFUSION OF LIGHT

A mirror reflects light in a regular way. This is true of any smooth and bright surface. Rough bodies reflect light in an irregular manner, and we see no reflection as such, but we see the object which reflects the light. This is called *diffused* reflection.

Light is diffused to a very great extent by particles of dust in the air which are too small to be seen. We obtain the light

from the sky in this manner of diffused reflection. Since the reflecting surface is so large, there are no definite shadows produced, the light fading away gradually on all sides of an object. The best light for the eyes is diffused light. Experiment 35 showed diffusion of light by means of the suspended particles in the water.

References: —

1. 1304 : 233. Diffraction of Light.
2. 1803 : 396-397. Diffusion of Light.
 - a. 1801 : 197-198. Diffused Reflection.
 - b. 1802 : 214. Irregular Reflection — Diffusion.
 - c. 1804 : 333-335. Diffused Light.
 - d. 1805 : 225. Diffusion of Light.
 - e. 1807 : 269-270. Diffusion of Light.
 - f. 1809 : 284-285. Diffused Light.
 - g. 1810 : 337-338. Regular and Irregular Reflection.
 - h. 1811 : 222. Diffused Reflection of Light.

75. TWILIGHT

After the sun sets, darkness does not begin immediately. In fact, the western sky becomes brighter a little while after the sun has set than it was just at sunset. This is called the afterglow, and is due to the reflection of light from particles in the higher air. In a very dry, clear atmosphere the afterglow is not so marked as it is in a locality where there is more water and dust held in suspension in the atmosphere. This dust is not to be confused with the dust of the earth as we find it in streets, for it is very fine and practically invisible.

Twilight means two lights, — the sun and the stars, — and lasts usually until the sun is 18° below the horizon.

References: —

1. 1002 : 138. Twilight Due to the Atmosphere.
2. 1103 : 24-25. Length of Twilight.

- a. 1305 : 101-102. Twilight.
- b. 1804 : 356. Cause of Twilight.

76. TRANSMISSION OF LIGHT — SHADOWS

Objects which allow light to pass through them undimmed are called *transparent*. If the light is much diminished, so that only a little shines through dimly, the object is called *translucent*. If no light can pass through a body, it is called *opaque*. When no light passes through an object, it casts a shadow which has the same outline as the object. Therefore we conclude that light travels in straight lines. The brighter the light, the denser is the shadow.

References: —

- 1. 1304 : 238-239. Transmission of Light through the Atmosphere.
- 2. 1601 : 8. Transmission of Light.
- 3. 1803 : 391. Shadows.
- 4. 1803 : 409-410. Why Light Travels in Straight Lines.
 - a. 1801 : 190-192. Shadows.
 - b. 1802 : 262. Shadows.
 - c. 1804 : 323-324. Shadows.
 - d. 1805 : 215-216. Transmission of Light.
 - e. 1805 : 220-221. Shadows.
 - f. 1806 : 142-143. Shadows.
 - g. 1807 : 260-261. Shadows.
 - h. 1808 : 374-375. Shadows.
 - i. 1809 : 276-278. Shadows — Pinhole Camera.

77. ECLIPSES

All planets, including the moon and the satellites of the other planets besides the earth, shine by light reflected from the sun. Most of the stars shine by their own light; that is, they are all bodies like our sun, although at a very great dis-

tance from it. If the light is shut off from the moon, or from any of the planets, those planets cannot be seen. We know that sometimes the earth passes between the sun and moon, and casts its shadow on the moon, rendering part of the latter invisible. We call this shadow over another heavenly body an *eclipse*. In the same way we can have eclipses of planets, but because they are so small, they are not noticed except through a telescope. There is one other kind of eclipse, which is the solar eclipse. This is caused by the moon passing between the earth and the sun. In that condition the shadow is upon us, and, if there were people on the moon, they would see that the earth was partially eclipsed.

References:—

1. 1002 : 273-275. Conditions for Eclipses.
2. 1002 : 284-287. Uses of Lunar and Solar Eclipses.
3. 1304 : 2. Shape of Earth Shown by Lunar Eclipse.
4. 1803 : 391. Shadow and Eclipses.
 - a. 1001 : 161-174. Eclipses — Kind and Number.
 - b. 1003 : 123-132. Eclipses of the Moon and Sun.
 - c. 1004 : 171-181. Eclipses of the Sun and Moon.
 - d. 1309 : 18-19. Eclipse of the Moon.
 - e. 1312 : 7-8. Eclipses.
 - f. 1808 : 375. Umbra and Penumbra.
 - g. 1809 : 276. Shadows.

78. MEASUREMENT OF LIGHT

Light can be measured by the direct illumination which it can produce, or by the shadows which it casts. The intensity of illumination is estimated in candle power, and the standard unit of measurement is a sperm candle, three-fourths of an inch in diameter, which burns at the rate of 120 grains per hour.

Before measuring light it is necessary to learn that the in-

tensity of illumination does not fall off proportionally to the distance, but to the distance squared. Thus a light at three feet gives but one-ninth the intensity of the same light at a distance of one foot.

If a standard candle and another source of light give the same illumination to two blocks of paraffin, separated by tin-foil, and placed between the two sources of light, both blocks appear the same shade. The distances of the two lights from the block may be measured, and the intensity of the unknown light may be computed.

Two shadows of a rod may be obtained side by side, one from a standard candle, and the other from the source of light which is to be measured. The distance of the unknown may be varied until the two shadows have the same density. Then the distances may be measured and the unknown candle power computed. Instruments such as those described are called *photometers*.

References: —

1. 1803 : 392-395. Intensity of Light — Candle Power.
 - a. 1801 : 193-195. Photometry.
 - b. 1802 : 208-211. Measurement of Light — the Photometer.
 - c. 1804 : 327-329. Intensity of Illumination — Photometry.
 - d. 1805 : 221-224. Intensity of Light — Photometry.
 - e. 1806 : 144-146. Measurement of Light — Photometry.
 - f. 1807 : 263-265. Intensity of Illumination — The Photometer.
 - g. 1808 : 377-379. Intensity of Illumination — Photometry.
 - h. 1809 : 279-281. Illumination, Photometry, Photometers.
 - i. 1810 : 333-337. Photometry, Photometers, Candle Power.

Experiment 38. — Candle Power — The Photometer.

Apparatus: A block of wood $3'' \times 3'' \times 1''$ with a peg $6'' \times 1''$ inserted in one side, two blocks $3'' \times 2'' \times 1''$, meter

stick, simple screen (cardboard 3" x 3" standing in slotted block).

Materials: One candle mounted on a block, four candles mounted on a block.

a. Place peg as near to screen as possible and place the one candle 20 cm. from the peg. How far away do you have to place the four candles to obtain a shadow as dense as the one candle casts? Repeat, placing single candle at a distance of 30 cm. A slightly darkened room is desirable.

b. Using this method test the candle power of an incandescent lamp at home. Also test the candle power of a gas flame and of a kerosene lamp or phototerme. Make your own photometer.

79. PHOTOGRAPHY

The waves near the violet end of the spectrum are the most active in the production of chemical changes, and they are also those which kill the bacteria of disease. Proper ventilation and sunlight can do much toward sanitation.

The chemical effect which is made use of to the greatest extent in the arts is that of sunlight upon the combinations of silver and other elements. Silver chloride and silver bromide turn dark in the sunlight, due to the separation of metallic silver from its compound. After a silver salt has been exposed to light, it can be assisted in the separation of metallic silver by certain chemicals, called *developers*. They are known chemically as reducing agents.

There are other photographic effects of light which are not commonly thought of under this title. The tanning of the skin is just as truly a chemical change, and a photographic result, as is the breaking down of a silver compound.

The details of photography, although very interesting, and

worthy of study, must be obtained from special books. The references give the chemistry of photography and some of its uses.

References: —

1. 1703 : 373-375. Photography.
2. 1803 : 433-434. The Camera.
 - a. 1003 : 233-236. Uses of Photography in Astronomy.
 - b. 1701 : 367-368. Photography.
 - c. 1704 : 354-356. Photography.
 - d. 1705 : 220-221. Photography.
 - e. 1706 : 312-313. Photography.
 - f. 1707 : 391-392. Photography.
 - g. 1708 : 375-376. Photography.
 - h. 1709 : 308-311. Photography.
 - i. 1711 : 155-158. Photography.
 - j. 1713 : 156-158. Photochemistry.

Experiment 39. — Effect of Light upon a Silver Salt.

Apparatus: Test tubes 6" \times $\frac{3}{4}$ ", funnel, ring stand.

Materials: Silver nitrate solution, 10 per cent, hydrochloric acid, 25 per cent, potassium bromide solution, 10 per cent, potassium iodide solution, 10 per cent, several sheets of filter paper.

- a. Take 5 c.c. of silver nitrate solution in a test tube and add hydrochloric acid, drop by drop, until there is no further precipitate formed. You have seen a chemical change. Silver nitrate has been changed into silver chloride. Filter, using the funnel, and expose the residue to direct sunlight. What happens? Repeat, using potassium bromide and potassium iodide solutions. Which material changes the fastest in the sunlight?

80. THE ATMOSPHERE AND ITS COMPOSITION

It is necessary for every living being to breathe, and the oxygen required is supplied from the atmosphere which surrounds the earth. This atmosphere obtains its name from two Greek words meaning "breath-sphere." It extends up from the earth between two and three hundred miles, but, since it is very compressible, fully half of all the atmosphere is within three miles of the surface of the earth.

The composition of the atmosphere is not uniform. This fact proves that the atmosphere is not a chemical compound, but merely a mixture of various gases. It can therefore be separated mechanically into its component parts, which consist roughly, by volume, of nitrogen, 78 per cent, oxygen, 21 per cent, and argon, 1 per cent. Besides these, very small quantities of carbon dioxide, ozone, dust, bacteria, and other rarer substances are present. The amount of carbon dioxide, bacteria, and dust depends upon the locality. These are called impurities, and pure air necessarily contains a very small amount of them.

References: —

1. 1002 : 135-143. The Earth's Atmosphere and its Effects.
2. 1304 : 229-231. Composition and Weight of the Atmosphere.
3. 1702 : 66-71. Air — a Mechanical Mixture.
4. 1803 : 68-70. Extent and Character of Earth's Atmosphere.
- a. 1102 : 2-8. Origin, Evolution, and Future of the Atmosphere — Its Composition.
- b. 1301 : 33-41. Composition and Height of the Atmosphere.
- c. 1302 : 273-275. Composition of the Atmosphere.
- d. 1303 : 23-26. The Atmosphere.

- e. 1305 : 55-58. Composition and Uses of Atmosphere.
- f. 1307 : 214-216. The Atmosphere and its Properties.
- g. 1701 : 83-91. The Atmosphere and its Properties.
- h. 1707 : 140-146. The Air and its Constituents.
- i. 1709 : 170-176. Composition of the Atmosphere.

Experiment 40. — Composition of Air.

Apparatus: Beaker 150 c.c., crystallization dish 4" in diameter, flat cork 1" in diameter.

Materials: Piece of yellow phosphorus size of a pea.

a. Fill crystallization dish half full of water, float the piece of phosphorus on the cork, and invert the beaker over it. If beaker does not stay in place, put a small weight upon it. Leave for twenty-four hours. How high does the water rise? Phosphorus combines with the oxygen of the air and leaves the nitrogen and other constituents of the atmosphere.

81. WEIGHT OF THE AIR

We learned in Section 2 that all matter is composed of molecules, and in Section 3 that the difference between solids, liquids, and gases is chiefly that of the relative velocity of the molecules. We would expect, therefore, that matter, in any of its states, would have weight on account of gravitation. See Section 39, Universal Gravitation.

The total weight of the air, or atmosphere, is not of special interest. The number of tons means nothing to us, for we cannot comprehend its vastness. What does interest us is the weight of the atmosphere on each square inch of surface, wherever we may be. The weight per unit area is called *pressure*. At the surface of the ocean the pressure of the atmosphere is 14.7 pounds per square inch, or, approximately, a long ton per square foot. Sea level is taken as the real level of the earth's surface.

The winds, which are to be studied in Section 94, show conclusively that air has weight. Otherwise, winds could not exist, or, if air did move, its effect would be invisible and unfelt.

1. 1304 : 231-232. Effect of Gravity on Air.
2. 1803 : 58. The Weight of Air.
3. Farmer's Bulletin No. 408 : 21-23. To Make a Balance.
 - a. 1102 : 143. The Weight of the Air.
 - b. 1305 : 56. Weight of Air.
 - c. 1309 : 202-203. Weight of the Air.
 - d. 1310 : 323. Substantiality of the Air.
 - e. 1311 : 225-226. Weight and Height of the Atmosphere.
 - f. 1801 : 122. Air has Weight.
 - g. 1804 : 155-156. Atmospheric Pressure.
 - h. 1805 : 129-130. Weight of the Air.
 - i. 1806 : 51-52. Weight of Air.
 - j. 1807 : 31-32. Weight and Pressure of the Atmosphere.
 - k. 1808 : 143. Weight of Gases.

Experiment 41.—Weight of Air.

Apparatus: Flask 250 c.c., rubber stopper to fit, ring stand, asbestos mat, burner, balances and weights. (Home-made balances will do.)

a. Put about 50 c.c. of water into the flask and let it boil vigorously. This drives out the air. While the water is boiling, insert the stopper and remove from the heat immediately. A cloth wet with cold water and wrapped around the flask will prevent all danger of an explosion. Weigh the flask. Then remove the stopper, thus admitting the air, and weigh again. Conclusions?

The home-made balances may be constructed from a stick three feet long with a cross section of $1'' \times \frac{1}{2}''$. Insert an iron screw eye in the edge of the stick at the middle, and suspend the stick by a string through the screw eye. A piece of iron, lead, or stone may be attached by loop of string, on one side of

the balance, and the flask may be suspended from the other side in a similar manner. Equilibrium may be easily obtained, which, when destroyed, shows a loss or gain of weight. The actual amount of loss or gain is of no consequence.

82. ATMOSPHERIC PRESSURE AND THE BAROMETER

The pressure of the atmosphere may be measured by an instrument called the *barometer*. It consists of a tube more than 30 inches long, closed at one end, filled with mercury, and inverted in an open dish of mercury. Within the tube the mercury falls until its surface is about 30 inches, or 76 centimeters above the open surface. Above the mercury in the tube is a vacuum. If the amount of mercury in the tube is weighed, and its weight is divided by the cross section of the tube, the result will approximate 14.7 pounds per square inch. Since water is only about one-fourteenth as heavy as mercury, a water barometer would have to be about fourteen times as long as a mercury barometer. That is, to be exact, the column of a water barometer would be 34 feet long.

At sea level the pressure averages 14.7 pounds per square inch, but at any other elevation it varies, being less on mountains, and greater in places below sea level. If we ascend and leave some of the atmosphere below us, it would seem natural for that part still remaining above us to have less pressure than the whole. Elevations may be roughly determined by means of the barometer. A difference of reading of one millimeter indicates a rise of about twelve meters. This corresponds to one-tenth of an inch for each 90 feet of elevation.

References: —

1. 1103 : 73-75. Air Pressure.
2. 1103 : 75-77. The Barometer.
3. 1304 : 421-422. The Barometer.

4. 1803: 59-63. The Barometer.
 a. 1102: 82-83. The Barometer.
 b. 1302: 275-276. The Barometer.
 c. 1303: 24-27. Pressure of the Atmosphere.
 d. 1309: 203-204. The Barometer.
 e. 1310: 374-375. The Barometer and Altitude.
 f. 1801: 122-126. The Barometer.
 g. 1802: 120-124. The Barometer.
 h. 1804: 157-163. How Atmospheric Pressure is Measured.
 i. 1805: 139-143. The Barometer.
 j. 1807: 33-36. Measurement of Atmospheric Pressure.
 k. 1808: 145-148. Measurement of Atmospheric Pressure.

Experiment 42. — Atmospheric Pressure.

Apparatus: Glass tumbler, card to cover it, glass tube $\frac{1}{4}$ " diameter, 40" long and closed at one end, small funnel, evaporating dish, ring stand, meter stick, iron pan, piece of cloth.

Materials: Mercury.

a. Fill the tumbler *full* of water, place the card over it, and, gently pressing on the card, invert the glass and card. Then remove the hand from the card, which will stay in place. What holds it there? By placing the inverted glass on a smooth table, the card may be removed, leaving the glass full of water, but inverted. How can such a glass of water be removed from the table without spilling any of the water?

b. Place the closed end of the glass tube upon the cloth, used as a pad in the pan, and fill with mercury, using the funnel. Half fill the evaporating dish with mercury, and, holding one finger firmly over the open end of the tube, invert it in the evaporating dish. Clamp the tube in the ring stand. How high does the mercury in the tube stand above the surface of mercury in the evaporating dish? Why is it not 30"? Do you think that there is a vacuum at the top of the tube?

83. BOILING FROM ANOTHER POINT OF VIEW

Section 23 states that change of state is due to added or subtracted molecular energy, while Section 2 states that molecular energy is heat. Since we have just learned that the atmosphere has pressure, we can now look upon the boiling of water in a different way from formerly.

As heat is added to water, its molecules move faster and faster, and those which are near the surface tend to pass away into the air. The molecules of the air, however, strike against the outcoming water molecules and force many of them back into the liquid. When the temperature of the water becomes so high that the average velocity of the water molecules is equal to the average velocity of the air molecules, the former possess enough energy to overcome the atmospheric pressure, and the water boils.

Since boiling is the overcoming of atmospheric pressure by the water molecules, if the pressure is less, the water boils at a lower temperature, for less energy is necessary. Therefore water boils at a lower temperature on a mountain top than in a valley. The altitude may be obtained, approximately, by means of a thermometer. Using a Centigrade thermometer, multiply the difference between 100° and the temperature at which boiling begins, by 295. This gives the altitude in meters. With the Fahrenheit thermometer, multiply the difference between 212° and the temperature at which boiling begins, by 533. This gives the altitude in feet. Since cooking is a chemical change due to temperature, a longer period of boiling is necessary on a mountain than at sea level to accomplish the same result.

In the laboratory, by means of the air pump, water may be

made to boil at any temperature between 100° C. and 0° C. Ice may be formed while the boiling continues. See Section 24, Evaporation Requires Heat.

References: —

1. 1803 : 204-206. Boiling Point Defined.
 - a. 1309 : 204. Boiling at High Altitudes.
 - b. 1801 : 280-281. Effect of Pressure on Boiling Point.
 - c. 1802 : 308. Ebullition.
 - d. 1804 : 281-283. Boiling Point.
 - e. 1805 : 338-339. Pressure and the Boiling Point.
 - f. 1807 : 200-202. Boiling and Pressure.
 - g. 1808 : 232-233. Boiling and Pressure.
 - h. 1809 : 189-191. Boiling and Pressure.
 - i. 1810 : 156-159. Boiling Points.
 - j. 1811 : 111-112. Effect of Pressure on Boiling Point.

Experiment 43. — Boiling at Reduced Pressure.

Apparatus: Glass flask 250 c.c., rubber stopper to fit, ring stand, asbestos mat, burner, beaker 100 c.c., battery jar 6" by 8".

a. Put about 75 c.c. of water into the flask, and let it boil vigorously. While boiling insert the stopper and invert the flask in a ring of the ring stand. Place the battery jar underneath and pour a few drops of water on the inverted flask. What happens? Continue to pour water on the flask until all action ceases. The temperature of the inclosed water will be about 15° C.

b. Why was water boiled vigorously? Why should only a little cold water be poured on at first? Why was it difficult to remove the stopper at the end of the experiment?

84. "SUCTION"

The quotation marks indicate a misnomer. Suction really is only half of the process. The other half is atmospheric

pressure. If we place a tube in a liquid, we may suck the air out of one end of the tube, but the liquid will not come up the tube unless the atmospheric pressure can act upon its surface. Even if the atmospheric pressure is free to act upon the surface of water, the latter will not rise more than 34 feet, as that is the limit of the height of a water barometer. See Section 82, Atmospheric Pressure and the Barometer. A rise of 34 feet would require that there be a complete vacuum above the water in the tube.

References: —

1. 1803: 59. Explanation of "Suction."
a. 1804: 167. Suction.

Experiment 44. — "Suction."

Apparatus: Test tube 8" by 1", rubber stopper with two holes. Glass tube to fit one hole.

a. Fill test tube with water; insert stopper. Placing finger on the empty hole in stopper, suck on tube.

What happens? Why? Remove finger and suck again. Explain.

85. PUMPS

Pumps are of two classes, the lift pump and the force pump. In the lift pump the effect of atmospheric pressure is made use of; that is, the action of the pump is the same as in the case of a person who is "sucking" on a tube. The atmosphere may be said to push on the other end. A pump, then, if perfect, cannot lift water higher than 34 feet. The usual pump cannot lift over 28 feet.

The force pump may be purely a force pump, in which case it is placed below the surface of the water, or it may be a combination lift and force pump. The height to which a force

pump may raise water is limited only by the force which is applied.

References: —

1. 1803 : 74-75. The Lift and the Force Pump.
2. Office of Experiment Stations 101. Machinery for Pumping Plants.
 - a. 1607 : 546. The Suction Pump.
 - b. 1607 : 551-552. Proper Place for Cylinder in the Well.
 - c. 1801 : 127-128. Air Pump.
 - d. 1804 : 173-174. The Lift and Force Pump.
 - e. 1805 : 149-151. The Lift and the Force Pump.
 - f. 1806 : 45-46. Pumps.
 - g. 1807 : 44-45. The Lift and the Force Pump.
 - h. 1808 : 157. The Suction and the Force Pump.
 - i. 1809 : 49-51. The Lift and Force Pump.
 - j. 1810 : 75-76. The Suction and the Force Pump.
 - k. 1811 : 25-38. Pump — Air, Lift, and Force.

86. THE SIPHON

The siphon consists of a bent tube with one leg effectively longer than the other. If such a tube is placed in a dish of water, with the longer leg outside, and the whole tube is filled with water, the water in the longer leg will run out. This tends to produce a vacuum in the tube, which is prevented by the atmospheric pressure, acting on the surface of the water and pushing it up the short leg of the siphon. Thus there is a continual flow of water. Unless the surface of the liquid in the dish is open to the pressure of the air, the siphon will not flow. The longer the long leg, the faster the water will flow through the siphon.

References: —

1. 1803 : 71-72. The Siphon.
 - a. 1801 : 132-134. The Siphon.

- b.* 1802: 126-128. The Siphon.
- c.* 1804: 170-172. The Siphon.
- d.* 1805: 148-149. The Siphon.
- e.* 1806: 45. The Siphon.
- f.* 1807: 45-46. The Siphon.
- g.* 1808: 152-153. The Siphon and its Action.
- h.* 1809: 47-49. The Siphon.
- i.* 1810: 74-75. The Siphon.

Experiment 45. — The Siphon.

Apparatus: Bottle, wide mouth, 500 c.c., rubber stopper with two holes to fit, short glass tube bent at right angles, long glass tube bent at one end so that the shorter leg reaches the bottom of the bottle while the other leg is about three feet in length. The lower end should be bent into a loop and the tube drawn out to form a small tube. Battery jar 6"×8".

a. Fill the bottle three-fourths full of water, insert the short right-angle tube in the stopper so that one end just passes through it; insert the short leg of the long tube in the other hole and push the stopper into bottle. Place the battery jar so as to catch the water, and "suck" on the outlet. What happens?

b. Place the finger on the open end of the right-angle tube. What happens? Why?

c. When the water has passed out of the bottle, fill it again and devise some method of starting the siphon besides "sucking."

87. NITROGEN AND ITS USES

Nitrogen forms no chemical compounds readily, and is said to be an inert gas. Its chief effect in the atmosphere is to dilute the oxygen. It is probable that animals could not live in an atmosphere of pure oxygen. Nitrogen has also another

very important use which has been discovered only within the last few years. Peas, beans, lentils, alfalfa, and a few other crops have on their roots bacteria which possess the power of absorbing the nitrogen from the air, and combining it with the oxygen and some of the salts of the earth to form nitrates. These nitrates are very valuable as plant foods. If there has been a crop of this kind in a field, there is always an excess of bacteria left in the ground. These bacteria go on producing the nitrates from the air, and make the soil very rich. Thus we know that nitrogen is used indirectly by plants, and that these have a never failing source of plant food.

References: —

1. 1103 : 7-8. Nitrogen in the Atmosphere.
2. 1304 : 229. Nitrogen in the Atmosphere.
3. 1407 : 233-235. Nitrogen in Relation to Plants.
4. 1503 : 94-95. Relation of Bacteria to Nitrogen.
5. 1601 : 110-112. Importance of Nitrogen in Plant Life.
6. 1605 : 116-122. The Sources and Losses of Soil Nitrogen.
7. 1702 : 44-45. Properties and Importance of Nitrogen.
8. 1703 : 107-109. Nitrogen and the Atmosphere.
9. 1710 : 6. Nitrogen.
- a. 1602 : 45-48. Clover and Other Plants take Nitrogen from the Air.
- b. 1603 : 33-35. The Root Tuberles.
- c. 1612 : 125-128. Nitrification of the Soils.
- d. 1701 : 78-80. Nitrogen and its Properties.
- e. 1706 : 61-64. The Atmosphere and Nitrogen.

Experiment 46. — To Prepare Nitrogen.

Apparatus: The same as in Experiment 3.

Materials: Ammonium nitrite.

- a. Place a teaspoonful of ammonium nitrite in the test tube, add twice the volume of water, and then follow the directions as given in Experiment 3.

b. State your conclusions in regard to nitrogen as a chemical element.

The nitrogen, as prepared in this experiment, is pure; that obtained from the air, in Experiment 40, was very impure.

88. EFFECTS OF PAINTING — WOOD PRESERVATION

Painting is looked upon more as a matter of decoration than as a protection from the effects of the weather. Really, however, beauty is a secondary consideration, although it should not be neglected. Pleasing combinations of tints and shades are capable of producing results which may go far toward making an otherwise ugly place appear attractive.

Whenever anything is exposed to the oxygen of the air, decay begins. Moisture aids this disintegration, as do also heat and cold. Paint excludes both the air and moisture, and prevents to a great extent the harmful effects of low temperature. All woodwork and metal work should be protected from the weather, and the protecting material should be carefully chosen.

There is nothing equal to linseed oil as a protective agent. In the oil there should be blended red lead, white lead, and, for some purposes, zinc white. Other oils and other materials do not produce equally lasting protection and should be rejected where protection is really desired. The color of the paints is a small matter, and all paints, except red, are made from white paint. It is often better to buy the white paint and color it to suit, as it is easier to detect foreign materials in white paint.

Wood can also be preserved by creosote or by zinc chloride. Graphite, applied to stoves, protects them like paint from atmospheric oxygen.

References: —

1. 1304:42. The Protection Due to Paint.
2. Forest Service Circular 139. A Primer of Wood Preservation.
 - a. 1706:361-362. Preparation of White Paint.
 - b. 1708:379. Preparation of White Paint.
 - c. 1709:356-358. Preparation of White Paint.
 - d. 1712:34. The Reason Why Paints Dry.
 - e. 1712:352-355. Paints and Painting.

Experiment 47. — The Testing of Paint.

Apparatus: Burner, blowpipe, piece of charcoal for blowpiping, six beakers 100 c.c., small paint brush.

Materials: Basic lead carbonate, red lead, litharge, whiting, barium sulphate, zinc oxide, linseed oil, fish oil, kerosene oil.

a. Make a little hollow in the charcoal and place a small amount of white lead in it. Then direct the blowpipe flame against the white lead so that half of the flame plays on it. This reduces the white lead to metallic lead. Repeat with red lead and litharge. More rapid results may be obtained with these by mixing an equal amount of ground charcoal with each before blowpiping.

b. Repeat (*a*) with zinc oxide and then with barium sulphate. What results do you obtain? Could you distinguish a lead compound from zinc oxide and from barium sulphate? These are the chief adulterants of paint.

c. Expose, in separate dishes, linseed oil, fish oil, and kerosene oil for twenty-four hours. What is the result? Which would protect wood the best? What is the harm of allowing paint to remain unused for some time?

d. Mix a little white lead in each of the oils and see which gives the best blend. Paint a board with each kind of "paint" and note the spreading ability of each.

e. Using linseed oil, mix a little zinc oxide, paint the board,

and examine in twenty-four hours. Repeat with barium sulphate and whiting.

Those who wish to make an exact test of paint may use the following method:—

To a small amount of the paint add ten times its volume of gasoline and shake well. Allow solids to settle, pour off the liquid, and repeat twice. Collect all of the liquid and allow it to evaporate, or heat it over water. *Look out for fire.* After cooling the resulting oily residue, add a few drops of concentrated sulphuric acid. Brown rings indicate linseed oil. Fish oil will not give the same test, and it may also be detected by its odor.

Evaporate to dryness the solids which were left, and add acetic acid. Both lead and zinc will dissolve. A residue indicates clay or barium sulphate (barites). Pass hydrogen sulphide (made by the action of hydrochloric acid upon ferrous sulphide in a hydrogen generator) into the clear solution. A black precipitate indicates lead. Filter, if there is a precipitate, and add ammonium hydrate. A white precipitate indicates zinc.

89. CARBON DIOXIDE

Carbon dioxide, although existing usually in an amount which varies from three parts in ten thousand to eight parts in ten thousand, nevertheless possesses thousands of tons of weight. The use of carbon dioxide is the maintenance of vegetable life. Most of the material contained in trees and coal once existed as carbon dioxide in the atmosphere. Under the effect of sunlight, the green coloring matter in the leaves, called *chlorophyll*, has the power of absorbing the carbon dioxide, retaining the carbon, and giving forth the oxygen.

Since animals inhale oxygen and exhale carbon dioxide, it is seen how nice is the balance between animal life and vegetable life.

References: —

1. 1103: 8-9. Carbon Dioxide.
2. 1304: 336. Importance of Carbon Dioxide to Plants.
3. 1407: 107-108. Effects of Carbon Dioxide on Plants.
4. 1702: 66-68. Carbon Dioxide in Air.
5. 1703: 112-113. Carbon Dioxide in the Atmosphere.
6. 1710: 9-10. Sources and Amount of Carbon Dioxide.
 - a. 1302: 274-275. Carbon Dioxide in Air.
 - b. 1612: 45-46. Carbon Secured by the Leaves from Carbon Dioxide.
 - c. 1706: 193-194. Properties of Carbon Dioxide and its Relation to Life.
 - d. 1707: 189-196. Chemical Properties of Carbon Dioxide; Respiration.
 - e. 1707: 196-198. The Cycle of Carbon in Nature.

Experiment 48. — Sources of Carbon Dioxide.

Apparatus: Funnel, syringe bulb with inlet and outlet tubes, glass tube $\frac{1}{4}$ " diameter, 8" long, test tube 8" \times 1", ring stand.

Materials: Limewater, candle.

a. Place bulb between funnel and glass tube, put candle under mouth of inverted funnel, and insert glass tube in test tube containing 5 c.c. limewater. Light candle. Gently force the air from the funnel into the limewater, and note how quickly it becomes milky.

b. Remove candle, take the apparatus to an open window, and repeat process (without candle) with fresh and clean limewater. What are your conclusions?

c. Remove funnel and gently breathe into some fresh lime-water. What must you conclude?

90. THE CHEMICAL ENGINE

We learned in Section 5, Oxygen, Its Uses and Action, that carbon dioxide bombs are used to extinguish fires. Carbon dioxide, in solution, is also thrown upon fires in streams, and the force which the streams possess is due to the carbon dioxide. This chemical is produced by the action of an acid upon some carbonate, which is the combination of carbon dioxide and some other element or elements. Where the action is to be slow, marble (calcium carbonate) and sulphuric acid are used. If greater rapidity is desired, sodium carbonate or sodium bicarbonate and sulphuric acid are used.

Chemical engines are of two kinds — the small size, which can be carried by a man, and the large size, mounted on a carriage to be drawn by horses. The first style cannot be readily refilled, but the large size is double, and one tank can be recharged while the other tank is in operation. Sodium carbonate is dissolved in the water which fills the tank, and a bottle, arranged to be inverted from the outside of the tank, is filled with sulphuric acid. The tank is then closed, and when a stream is needed, the sulphuric acid bottle is inverted. The chemical action is very sudden, and the engine can be used at once. The pressure of the gas drives out the water with great force. Considerable quantities of carbon dioxide are held in solution. When the water reaches the fire, the chemical is freed and excludes the oxygen from the combustibles.

References: —

1. 1703: 192-193. Preparation of Carbon Dioxide.
 a. 1701: 206. Carbon Dioxide a Fire Extinguisher.
 b. 1704: 177. Preparation of Carbon Dioxide.
 c. 1706: 192-195. The Preparation and Properties of Carbon Dioxide.

- d. 1707: 192-194. Preparation and Properties of Carbon Dioxide.
- e. 1709: 244-246. Preparation and Properties of Carbon Dioxide.

Experiment 49. — Preparation of Carbon Dioxide — the Chemical Engine.

Apparatus: Bottle 250 c.c., wide mouth, rubber stopper to fit, with two holes, thistle tube with stopcock, right-angle tube, one leg long enough to reach the bottom of the bottle and the other leg drawn out to form a small nozzle.

Materials: Sodium bicarbonate, hydrochloric acid of full strength, marble.

a. Fill the bottle nearly full of cold water, and add about two teaspoonfuls of sodium bicarbonate. Insert thistle tube and the right-angle tube in the two holes of the stopper, and push them in so that they both reach nearly to the bottom of the bottle. Shake the bottle gently until the sodium bicarbonate is dissolved. Then add hydrochloric acid, by means of the thistle tube, allowing only a little to pass at a time. Tip the bottle so that the liquid passes into the sink, for if the liquid touches skin or clothes, they will be burnt by some of the uncombined acid.

b. Put a few drops of half-strength hydrochloric acid upon marble. The bubbles are carbon dioxide. If hydrochloric acid is placed upon any rock, and bubbles are formed, they indicate that the rock is a carbonate.

91. OTHER CONSTITUENTS OF THE ATMOSPHERE

Besides these three principal ingredients, oxygen, nitrogen, and carbon dioxide, there are several others, of which dust and bacteria are the most important.

sun. The ocean is transparent and allows some of the energy to pass through. There are also convective currents in the ocean which cause much of the water to be raised to the same temperature, while it is only the surface of the earth that is warmed. Therefore the air over the land becomes much hotter than the air over the water, expands, and is pushed up by the colder air coming in from the ocean. This produces the sea breeze. In the night the land cools off faster than the ocean, because water, owing to its great capacity for heat, retains heat longer than any other substance. Then the air over the ocean is warmer than over the land, and the cooler air of the land goes out to take the place of the warmer air over the ocean.

References: —

1. 1103 : 101-104. The Winds of the Globe.
2. 1304 : 255-262. Different Kinds of Winds.
- a. 1102 : 112-139. All the Kinds of Winds.
- b. 1301 : 90-100. Planetary Winds.
- c. 1302 : 304-311. The Relations of Pressure and Winds.
- d. 1305 : 81-89. Three Classes of Winds.
- e. 1306 : 70-84. Classification of the Winds.
- f. 1308 : 94-99. Movements of the Atmosphere.
- g. 1309 : 218-225. Atmospheric Circulation.
- h. 1310 : 386-396. General Circulation of the Atmosphere.
- i. 1311 : 266-268. Origin of Terrestrial Winds.
- j. 1312 : 368-370. Classification of the Winds.
- k. 1313 : 185-188 Kinds of Winds.

96. VELOCITY OF WINDS

The velocity of winds depends upon the difference of temperature in the place from which the wind comes and the place toward which the wind is going. The greater the difference of temperature between the two places, the greater the veloc-

ity of the wind. It also depends upon certain whirls in the atmosphere, which are not very well understood, but which will be discussed when we consider the weather and its causes. The recording of weather changes, including the measurement of wind velocity, is given in Section 109, Weather Instruments.

References:—

1. 1103 : 106-113.	Variation in the Velocity of the Winds.
2. 1304 : 422.	Anemometer, or Wind Measurer.
a. 1102 : 94-95.	Force and Velocity of the Wind and its Measurement.
b. 1301 : 99-101.	Velocity of Wind.
c. 1302 : 288-289.	Pressure and Velocity of Winds.
d. 1303 : 37-38.	Observation of Winds.
e. 1309 : 218.	Winds and their Measurements.
f. 1312 : 376.	High Velocity of Winds from Tornadoes.
g. 1607 : 532.	Relation of Wind Pressure to Wind Velocity.

97. RESOLUTION OF FORCES

In Section 38 we learned that each force acts independently of all other forces which may be acting at the same time. We also learned that the result obtained by two forces could be accomplished by one force properly directed. It will not seem strange, then, to learn that any force may be resolved, or analyzed, into two or more components. The components usually desired are the two forces, which, acting at right angles, could produce the single force under consideration. These forces may be obtained geometrically or graphically.

The given force should be considered as the hypotenuse of a right triangle. The other forces, that is, the components, are the base and altitude of the right triangle. Since an in-

through it quite readily; nevertheless, some of the energy is stopped, and where any kind of energy is stopped, heat is always produced. This is the direct method of heating.

When the sunlight strikes the earth, which is opaque, all of the energy is stopped, and it is all turned into heat. Thus the surface of the earth becomes very warm. It warms the air above it by conduction; this warmed air expands and is pushed up by the colder air on all sides, and we say that air is becoming warm by convection. Most of the heat of the air is obtained in this indirect way. The earth is prevented, to a certain extent, from becoming too hot by the cold air coming in on all sides.

References: —

1. 1103 : 182-183.	The Heat in the Air.
2. 1304 : 238-239.	The Warming of the Air.
3. 1601 : 3-4.	Air Warmed by Sunshine.
4. 1803 : 220-221.	Warming of the Air and Ocean.
5. 1803 : 223-224.	Warming and Ventilation of Houses.
a. 1102 : 77.	The Motion Conditions of General Convection.
b. 1301 : 64-66.	Effect of Heat on Air.
c. 1303 : 28-29.	Temperature of the Atmosphere.
d. 1306 : 68-69.	General Circulation of the Atmosphere Due to Heat.
e. 1307 : 216-217.	Effects of Temperature on the Air.
f. 1310 : 334-336.	The Heating of the Atmosphere.

94. WINDS

Air in motion is wind. The air has a definite weight, which produces the pressure of about fourteen and seven tenths pounds per square inch, or about one ton per square foot, on the entire surface of the earth. If the air in one section is

warmed, it expands, and, becoming lighter, is shoved upward by the air flowing in from all directions to take its place. This produces the winds, and no matter what kind of winds they may be, they are all produced in the same way.

References: —

1. 1103 : 73-80.	Air Pressure.
2. 1103 : 180-192.	General Circulation of the Atmosphere.
3. 1304 : 255-262.	Winds of the Earth.
4. 1601 : 4.	Winds Caused by Sunshine.
5. 1803 : 58-63.	Pressure in Air.
a. 1102 : 11-14.	Pressure and Extent of the Atmosphere.
b. 1102 : 82-85.	Measurement of Atmospheric Pressure.
c. 1301 : 85-90.	Air Pressure.
d. 1303 : 24-26.	Pressure of the Atmosphere.
e. 1305 : 78-89.	Movements of the Atmosphere.
f. 1306 : 83-84.	The Nature of Winds.
g. 1307 : 214-225.	The Atmosphere and Winds.
h. 1308 : 94-99.	Movements of the Atmosphere — Winds.
i. 1804 : 155-163.	Atmospheric Pressure.

95. KINDS OF WINDS

All general breezes of the earth are caused by the air of the equator being hotter than the air at the poles. These breezes, or winds, are called *terrestrial winds*, and are divided into four classes, starting from the equator, — the doldrums, the trades, the prevailing westerlies, and the circumpolar whirls. There are local breezes called the sea breeze and land breeze, the day breeze and the night breeze, the mountain breeze and the valley breeze; but they are all based upon the same principle. The land and sea breezes may be taken as examples for explanation.

In the daytime the land becomes warm faster than the ocean, because the land is opaque and stops the energy of the

sun. The ocean is transparent and allows some of the energy to pass through. There are also convective currents in the ocean which cause much of the water to be raised to the same temperature, while it is only the surface of the earth that is warmed. Therefore the air over the land becomes much hotter than the air over the water, expands, and is pushed up by the colder air coming in from the ocean. This produces the sea breeze. In the night the land cools off faster than the ocean, because water, owing to its great capacity for heat, retains heat longer than any other substance. Then the air over the ocean is warmer than over the land, and the cooler air of the land goes out to take the place of the warmer air over the ocean.

References: —

1. 1103 : 101-104. The Winds of the Globe.
2. 1304 : 255-262. Different Kinds of Winds.
 - a. 1102 : 112-139. All the Kinds of Winds.
 - b. 1301 : 90-100. Planetary Winds.
 - c. 1302 : 304-311. The Relations of Pressure and Winds.
 - d. 1305 : 81-89. Three Classes of Winds.
 - e. 1306 : 70-84. Classification of the Winds.
 - f. 1308 : 94-99. Movements of the Atmosphere.
 - g. 1309 : 218-225. Atmospheric Circulation.
 - h. 1310 : 386-396. General Circulation of the Atmosphere.
 - i. 1311 : 266-268. Origin of Terrestrial Winds.
 - j. 1312 : 368-370. Classification of the Winds.
 - k. 1313 : 185-188 Kinds of Winds.

96. VELOCITY OF WINDS

The velocity of winds depends upon the difference of temperature in the place from which the wind comes and the place toward which the wind is going. The greater the difference of temperature between the two places, the greater the veloc-

ity of the wind. It also depends upon certain whirls in the atmosphere, which are not very well understood, but which will be discussed when we consider the weather and its causes. The recording of weather changes, including the measurement of wind velocity, is given in Section 109, Weather Instruments.

References: —

1. 1103 : 106-113. Variation in the Velocity of the Winds.
2. 1304 : 422. Anemometer, or Wind Measurer.
- a. 1102 : 94-95. Force and Velocity of the Wind and its Measurement.
- b. 1301 : 99-101. Velocity of Wind.
- c. 1302 : 288-289. Pressure and Velocity of Winds.
- d. 1303 : 37-38. Observation of Winds.
- e. 1309 : 218. Winds and their Measurements.
- f. 1312 : 376. High Velocity of Winds from Tornadoes.
- g. 1607 : 532. Relation of Wind Pressure to Wind Velocity.

97. RESOLUTION OF FORCES

In Section 38 we learned that each force acts independently of all other forces which may be acting at the same time. We also learned that the result obtained by two forces could be accomplished by one force properly directed. It will not seem strange, then, to learn that any force may be resolved, or analyzed, into two or more components. The components usually desired are the two forces, which, acting at right angles, could produce the single force under consideration. These forces may be obtained geometrically or graphically.

The given force should be considered as the hypotenuse of a right triangle. The other forces, that is, the components, are the base and altitude of the right triangle. Since an in-

finite number of triangles can be constructed upon a given line, any combination of two forces may be obtained which are at right angles to each other.

Any force which is not applied in the direction of the desired movement has a component of loss. Thus the traces of a harness should be as nearly parallel to the ground as possible, and the tow rope of a towboat should be moderately long to avoid the sidewise pull. Similarly, a sprinter in starting should keep his "push-off" leg parallel to the ground.

References: —

1. 1803: 14-19. Composition and Resolution of Forces.
 - a. 1607: 492-493. The Best Position of the Traces of a Harness.
 - b. 1801: 42. Resolution of a Force.
 - c. 1802: 80-81. Resolution of Forces.
 - d. 1804: 62. Resolution of Forces.
 - e. 1805: 44-47. Resolution of Forces.
 - f. 1806: 116-117. Composition and Resolution of Forces.
 - g. 1807: 54. Resolution of a Force.
 - h. 1808: 46-47. Resolution of Forces.
 - i. 1809: 74-79. Composition of Forces.
 - j. 1810: 53-55. Resolution of Forces, Velocities, and Accelerations.
 - k. 1811: 366-369. The Resolution of Forces.

Experiment 50. — Resolution of Forces.

Apparatus: Block of wood $6'' \times 3'' \times \frac{1}{8}''$, set of weights, spring balance, protractor, board $3' \times 5'' \times \frac{1}{8}''$ with a narrow strip of wood nailed along one edge, two thumb tacks, string.

a. Drive a nail in the center of the flat side of the $6'' \times 3''$ block, and fasten the protractor with thumb tacks so that its diameter lies lengthwise of the block, its center point against the nail. Tie a string to the nail and make a loop at its end for the spring balance. Place the block on the long board,

against the strip, and weight it until there is a definite pull, when the balance is drawn along with a uniform motion.

b. What is the pull when the balance is drawn lengthwise of the board? This is the total force which is necessary to move the block with its load of weights. Now draw the balance a little toward the strip so that the string crosses the protractor at an angle of 5° from the line of the block's motion. What pull is necessary? What has happened to the extra force? Increase the size of the angle, and note the increasing loss of force. A pull, or a push, at an angle to the desired direction of motion, has a component of loss.

98. THE THEORY OF THE KITE

With the kite it is necessary to resolve the force of the wind, which blows for the most part parallel with the earth's surface, into two forces. One must act at right angles to the surface of the kite, as the effective force, and the other parallel to the surface of the kite, though not affecting the latter. The perpendicular force must then be resolved into two forces, one acting parallel to the string, producing the "pull" of the kite, and the other acting at right angles to the string, producing the lifting of the kite itself. By regulating the angle at which the string leaves the kite, the latter may be made a "puller" or a "high flyer." The more the top of the kite is inclined toward the string, the higher the kite will fly until the limit of height for that kite is reached.

Kites may be balanced by means of a tail or by so shaping the surface of the kite that it sheds the wind equally from the two sides. The Malays have evolved this style, and it is the best for simple construction. The box kite, which consists of two or more cells into which the wind blows, is more com-

plicated, but has a greater lifting power. Kites are used for observational purposes, usually in war, and to obtain data concerning the conditions of the upper atmosphere.

Reference: —

1. 1803: 249. **Franklin's Kite.**

Experiment 51. — To Make a Malay Kite.

Materials: Two sticks $5' \times \frac{1}{2}'' \times \frac{1}{2}''$, string, light paper, flour paste.

a. Cross the two sticks at the middle point of one, one fifth its length from an end of the other, and bind together. Slot the ends of the sticks and run a string around the kite frame. Paper the kite, turning over as small a margin as is convenient, say one inch, and paste with boiled flour paste. The bridle should be fastened at the crossing of the sticks and at the lower end of the upright stick, and the loop should be about eighteen inches from the kite. Tie a string at one end of the horizontal stick, and then bend this stick backward so that when its other end is tied by the string the distance between the string and the crossing of the sticks will be one fifth the length of the stick. To fly the kite, tie a loop in the bridle at such a place as will cause the kite to fly high or low, as desired. This point can be determined by holding the kite by its bridle in the wind. If not satisfactory, adjust again, as practice and theory must go hand in hand.

The author has devised a kite which makes use of curved surfaces. Because of the curves it is hard to paper, although with care this can be accomplished. A cloth covering is preferable, as it is in all kites larger than $5' \times 5'$. This design may be made in the following manner: —

Take two sticks (white cedar wood is best) $1.5 \text{ cm.} \times .7 \text{ cm.}$ tapered to $1 \text{ cm.} \times .4 \text{ cm.}$, 110 cm. long, and lash them together

at right angles, allowing the thicker ends to project 2 cm. The smaller ends of these two sticks are lashed to the ends of a third stick, 1 cm. \times .7 cm., tapered to 1 cm. \times .4 cm. at each end, 170 cm. long, for a distance of 20 cm. from each end. This forms a triangle with all three sides bending in. Now strongly lash the ends which project 2 cm. to a stick 1.5 cm. \times 1.5 cm., tapered to 1.5 \times .7 cm., 170 cm. long 7 cm. from the larger end. Tie a string, at its middle point, to the smaller end of this last stick, having the two ends of the string long enough to reach the outer ends of the cross sticks; pull down the ends of the cross sticks equally until a line joining their two extremities is 135 cm. distant from the bottom of the kite. Paper the kite by fitting the paper over the string first, covering the cross sticks last. Leave the paper quite loose. Fasten the bridle as in the Malay kite.

If this kite is made so that it balances and sheds the wind equally from both sides, it may be so hung that it will fly at a very slight angle from the vertical. If for any reason the kite comes down, it lands like a bird, without damage to itself.

99. THE THEORY OF THE AËROPLANE

The aëroplane consists, essentially, of a plane, or planes. It is forced through the air by means of powerful propellers, differing but slightly from electric fans. The theory of the aëroplane is very similar to that of the kite. In the case of the kite the plane stays still and the wind goes by; with the aëroplane the air may be stationary, but the plane moves. In both cases there is a component of the total force which is opposed to gravity, and the kite and the aëroplane rise, although both are heavier than air. There must be motion between the planes and the air in both cases.

It must be remembered that the complete theory of the aëroplane, or even of the kite, is much more complex than has been stated, and many other factors enter into consideration. It might be well to state that the effective area of a plane increases with the velocity, since the air is forced more to the sides; and curved planes give a greater component of lift, due partly to reaction.

Reference:—

1. 1809:79. The Aëroplane.

Experiment 52. — To Make a Boomerang.

Materials: Piece of pasteboard 6" square.

a. Cut from the pasteboard a piece similar to a carpenter's square, having both sides six inches long and one and one half inches wide. Round the ends so that they are semicircles, and round the outside angle, formed by the two sides, so that it is a quarter circle.

b. Place the boomerang on a book so that one end points toward you and the other end projects at right angles to the edge of the book. Incline the latter at an angle of 30° from the horizontal, and hit the projecting end of the boomerang a smart, straight blow with a pencil.

After a few trials the boomerang can be made to go some distance away and upwards, and then return to the feet of the operator.

This toy illustrates the first law of motion, in that it maintains its motion, revolving continually in the same plane. The aëroplane glides through the air, and is prevented from falling to earth, and, in fact, leaves the earth, by means of its inclined planes, in much the same way as the boomerang behaves.

100. SAILING A BOAT

The kite and the aëroplane both act in a single medium; that is, they move in air only. A sailboat moves in water, but obtains its energy from the motion of the air. The theory of sailing a boat, however, does not greatly differ from the theory of the kite.

The force of the wind, as it strikes against the sails, may be resolved into one component perpendicular to the sail, and into another component parallel to the sail. The latter has no effect if the sail is flat. The perpendicular component can be resolved into one component acting in the direction of the boat's motion, which tends to send the boat ahead, and into another component acting at right angles to the boat's motion. This causes leeway and may be prevented to some extent by a deep keel, or by a centerboard.

The windmill acts very similarly to a sailboat when the latter is sailing across the breeze, with the exception, of course, that the windmill is constrained to revolve.

It may be well at this point to state again that this theory is only part of the whole theory and does not take into consideration the fact that with sails of boats and with blades of windmills the curved surface plays a prominent part in the production of motion. Reaction also enters into the problem of transforming the energy of the wind into useful work.

References: —

- a. 1607: 531-534. The Windmill.
- b. 1804: 63. The Theory of Sailing.
- c. 1809: 78-79. Boat Sailing.
- d. 1811: 368-369. The Theory of Sailing.

Experiment 53. — To Make a Windmill.

Materials : Piece of paper, eight inches square, pin.

a. Fold the paper diagonally twice, then tear, or cut, along the diagonals two thirds the distance from the corners to the center. Fasten alternate corners to the center with a pin. This produces a four-blade windmill which will revolve in the current of air produced by a person while walking. Such wind wheels may be made double, or of any number of sheets, and in colored paper be used for purposes of decoration.

101. HUMIDITY

In addition to the various gases which compose the atmosphere, there is a varying quantity of water vapor, which is the most important substance. Without this water vapor there could be no growth of vegetation, for there could be no rain under any circumstances. Water exists in several states; it appears as clouds, fog, mist, rain, dew, frost, snow, hail, and ice. Water vapor is invisible.

The water vapor makes the air damp, although it does not affect the amount of air which is present. That is, water vapor does not crowd out the air, and, on the other hand, no more water vapor would be present, under given conditions of temperature and pressure, if the air were wholly removed.

Sulphuric acid has the power of absorbing water, and an open dish of this acid is used to remove the moisture from within clock and balance cases, in order to prevent the rusting of delicate parts. Such a dish of acid, if exposed to the open air, rapidly gains in weight, due to the water which is absorbed from the air.

The total amount of water vapor which the air can hold under given conditions is called *saturated humidity*; the

total amount which the air does hold is called *absolute humidity*. The absolute humidity divided by the saturated humidity is called *relative humidity*. It is the latter which concerns us. The higher the temperature, the more water can exist as vapor; therefore warming a house seems to dry it, although the same amount of water may be present as when it was cold. The relative humidity should be between 70 per cent and 75 per cent. A further consideration of humidity will be studied in Section 190, Dangers of Vitiated Air, in connection with ventilation.

References: —

1. 1103 : 122. Atmospheric Humidity.
2. 1304 : 244-245. Humidity.
3. 1803 : 100. Humidity of the Atmosphere.
 - a. 1102 : 144-146. Humidity.
 - b. 1302 : 281-282. Humidity.
 - c. 1303 : 60-61. Humidity.
 - d. 1305 : 66-68. Humidity.
 - e. 1308 : 93. Humidity and its Condensation.
 - f. 1309 : 239. Humidity.
 - g. 1310 : 364-366. Humidity.
 - h. 1311 : 226-227. Humidity.
 - i. 1312 : 379-380. Absolute and Relative Humidity.

EXPERIMENT FOR THE TEACHER

Moisture in the Air

Expose a thin layer of sulphuric acid (concentrated) in a large open glass dish. Weigh before and after exposure of twenty-four hours.

102. DEW

There is an old saying that dew falls, but this is not the truth, since the dew is formed at the place where it appears.

Water vapor, when cooled to its point of saturation, called the *dew point*, condenses into liquid water. Due to radiation, the surface of the ground, and especially the vegetation, becomes cool after sunset, and rapidly lowers the temperature of the surrounding air. This causes the invisible water vapor to condense as dew.

Whenever water vapor condenses, it gives out large quantities of heat, as we have learned in the case of condensation of steam in Section 25. If water vapor condenses at a lower temperature than 100° C., it gives out more heat than it does at the boiling point. Each gram of water vapor, when it condenses, gives out a number of calories which can be estimated roughly by multiplying the temperature by six tenths and subtracting this result from 596. For the above reason, if the relative humidity is great, the temperature will remain more constant during the night than it would if the air were very dry.

References :—

1. 1103 : 123-124. The Dew Point and the Measurement of Humidity.
2. 1103 : 162. Dew.
3. 1304 : 246. Dew.
4. 1803 : 97-99. Condensation of Water from the Air.
5. Weather Bureau Bulletin No. 235. Psychrometric Tables.
 - a. 1102 : 155-157. Formation of Dew and Frost.
 - b. 1301 : 130-131. Dew and its Formation.
 - c. 1302 : 285-286. Dew and Frost.
 - d. 1303 : 61-62. Dew and Frost.
 - e. 1305 : 75. Natural Formation of Dew.
 - f. 1306 : 107-108. Dew.
 - g. 1307 : 232-234. Dew Point and Dew.
 - h. 1309 : 241-242. How Dew is Formed.
 - i. 1310 : 372-373. Dew and Frost.
 - j. 1311 : 227-228. Dew and Frost.

Experiment 54. — Dew Point.

Apparatus: Small, brightly polished, nickel-plated, cylindrical brass dish 1" \times 3" (a shaving-stick box is excellent, for this purpose), rubber stopper with three holes, to fit, thermometer, all glass, right-angle glass tube, syringe bulb, rubber tubing, ring stand.

Materials: Ether.

a. Fill brass tube one third full of ether, push the thermometer into one hole, the right-angle tube into a second hole, of the stopper, and insert it in the top of the brass tube. Attach the syringe bulb, by means of rubber tubing, to the right-angle tube. Support the brass tube by its stopper.

b. By means of the bulb cause air to pass through the ether, taking care not to breathe on the tube. The temperature falls rapidly, and soon moisture will begin to collect on the outside of the brass tube. Stop forcing air in, and read the thermometer. Wait until the moisture disappears, and read the thermometer again. The average of the two readings is the dew point.

c. Repeat this experiment early some morning.

Knowing the dew point and the temperature, the relative humidity may be discovered by means of tables. See references.

103. FROST

Frost is formed in much the same way as dew, although in this case the formation takes place below the freezing point of water, which is 32° Fahrenheit. The invisible water vapor passes directly from the gaseous state to the solid state, without any intermediate stage. If the wind is blowing on a cold night, there will be very little frost, and perhaps none at all, because as fast as the air is cooled more air comes in; thus the

temperature of any particular section of the air is not lowered below its freezing point. Again, if there is much fog, there will be no frost, since the formation of the fog raises the temperature of the air. However, where the air has very little water vapor, we may have what is called a black frost, which merely means that the water in the plants themselves is actually frozen, and when this thaws out, they wilt and die. This will explain the peculiar statement which people make, namely, that after a cold night it is the sun which destroys the flowers.

References:—

1. 1103: 290-291. Frost.
2. 1304: 246. Frost.
3. Farmers' Bulletin No. 104. Notes on Frost.
 - a. 1101: 135. Formation of Frost.
 - b. 1102: 156-158. Frost and its Prediction.
 - c. 1301: 132. Frost and its Formation.
 - d. 1302: 285-286. Dew and Frost.
 - e. 1305: 75. Hoarfrost.
 - f. 1306: 108. Frost.
 - g. 1310: 367-368. Fog, Frost, and Cloud.
 - h. 1311: 227-228. Dew and Frost.
 - i. 1312: 381-382. Dew and Frost.
 - j. 1807: 199. Conditions for Frost.

104. FOG AND CLOUDS

These two are very much the same, the fog being either at the surface of the earth or a little above it, while the clouds are usually half a mile or more high. The conditions which cause their production are very similar: a warm mass of air carrying large quantities of water vapor is cooled, for various reasons, which causes the water vapor to condense into a great many minute drops which form the fog or clouds.

References: —

1. 1103 : 129-137. Formation of Fog and Clouds. Classification of Clouds.
2. 1304 : 247-248. Fog and Clouds.
3. Weather Bureau. Classification of Clouds. With Chart.
 - a. 1102 : 158-159. Fog and the Cause of Condensation.
 - b. 1301 : 133-140. Fog and Clouds.
 - c. 1303 : 62-64. Clouds, Fogs, and Mist.
 - d. 1305 : 68-70. Fog and Clouds.
 - e. 1306 : 169-174. Fog and Clouds.
 - f. 1307 : 235-238. Clouds and their Nomenclature.
 - g. 1311 : 228-231. Fog and Clouds.
 - h. 1309 : 242-247. Fog and Clouds.
 - i. 1310 : 367-373. Cloud, Dew, and Frost.
 - j. 1312 : 382-385. Clouds.

105. SNOW AND HAIL

Snow is not frozen rain, but may be considered as aerial frost. Snow is formed where water vapor is cooled so suddenly that it passes directly from the vapor state into the solid state, without any intermediate liquid state. That is, the formation of snow is an example of *sublimation*. Snow crystals are very beautiful and are of many varieties, although all are six-sided, or six-spoked, at angles of 60°.

Hail is frozen rain. The formation of the larger hailstones requires quite a long period of time and many ascents and descents before they finally fall to the ground. The rain falls through a layer of cold air and is partly frozen; then other currents of air force the tiny hailstones back into the colder layer of air, where they grow by the addition of more freezing water. This process continues until the ascending currents cannot sustain the increasing weight of the hailstones, which then fall for the last time. Much damage to windows

and to crops may be caused by the larger hailstones, which sometimes measure as much as two to three inches in diameter.

References:—

1. 1103 : 159.	Hail and Snow.
2. 1304 : 249-250.	Snow and Hail.
3. 1803 : 99.	The Formation of Clouds, Rain, Hail, and Snow.
4. Weather Bureau.	Photomicrographs of Snow Crystals.
a. 1102 : 286-287.	Snow and Hail.
b. 1302 : 284-285.	Snow and Hail.
c. 1303 : 70.	Snow and Hail.
d. 1305 : 72-73.	Snow and Hail.
e. 1309 : 258-259.	Hail and Snow.
f. 1807 : 200.	Snow and Hail.

Experiment 55. — Sublimation.

Apparatus: Burner, test tubes $6'' \times \frac{3}{4}''$, test-tube holder, stirring rod of glass.

Materials: Ammonium chloride, iodine, alcohol.

a. Place a quarter teaspoonful of ammonium chloride in a test tube and heat it. Does the ammonium chloride melt? Stick the rod into the test tube for a minute, then remove the tube from the burner. Examine the rod. What has happened?

b. Repeat, using a few grains of iodine. What is the color of iodine? Of the vapor of iodine? Describe the result.

c. Dissolve the iodine with alcohol. State the difference between melting a substance and dissolving it in some solvent.

106. RAINFALL — CYCLONES

If the cooling of the warm air is carried beyond the formation of clouds, there will be so much water condensed that it

can no longer float, or, to say the same thing in other words, the particles or little drops of water will come together and form large drops which are too heavy to remain in the air. Rain then takes place, and continues if the condensation continues. The study of the causes which produce rain is one in which the United States Government is much interested, and for which large sums of money are spent annually. Thanks to these investigations, which are country-wide, we are able to state definitely just what the conditions are preceding a rainstorm.

In the prevailing westerlies there are vast whirlpools, just as there may be in flowing water. Underneath one of these whirlpools there is less air pressing upon the earth than there is anywhere near the whirlpool. We call this section a "low" because a barometer, which indicates the pressure of the air, would show a low pressure. Just as in a whirlpool in water the neighboring water rushes in to fill up the whirlpool, so the air rushes from all directions, over a space of thousands of square miles, towards the center of one of these lows. If a low passes to the north of us, the wind will come from the south to fill it up. This south wind, on account of its warmth, contains a great deal of water vapor. As it travels north it becomes colder, about one degree Fahrenheit for each geographical degree, roughly, sixty-eight miles. The air also rises as it comes north, and becomes cooler, one and six tenths degrees Fahrenheit for every three hundred feet which it ascends. Both these conditions rapidly lower the temperature of the whole mass, and the point at which the air can no longer hold water vapor is rapidly reached. This is called the *saturation point*, and at this point fog and cloud are produced. Any further cooling of the air produces rain. The scientific name for a "low" is "cyclone."

References: —

1. 1103 : 142-145. Rainfall and its Causes.
2. 1304 : 249-250. Rain, Snow, Hail.
3. 1304 : 262-266. Storms and their Causes.
 - a. 1102 : 285-292. Causes, Measurement, and Distribution of Rainfall.
 - b. 1302 : 327-334. Rainfall and its Distribution.
 - c. 1305 : 71-73. Rain, Snow, Sleet.
 - d. 1307 : 239-246. Rain, Rainfall, Snow, and Hail.
 - e. 1308 : 110-112. Rainfall.
 - f. 1309 : 249-253. Causes of Rainfall.
 - g. 1310 : 373. Rain Making.
 - h. 1311 : 231-236. Rainfall.
 - i. 1312 : 386. Cyclonic Rains.
 - j. 1313 : 190-191. Causes of Rainfall.

107. WEATHER OBSERVATIONS

In about eighty places scattered over the United States, the United States Government takes observations of the weather every morning except Sunday, at 8 A.M., Washington, D.C., time. These records are then compiled at various head stations, where each day at about 2 o'clock, Washington time, a map is published which shows the conditions of the weather all over the country. These maps are distributed freely to schools and to other public institutions. One who will study such a map will obtain a great deal of information concerning the weather, and if a series of maps is examined carefully, not merely scanned, nearly every change known about the weather will be manifest.

References: —

1. 1103 : 274-292. Weather Maps and Weather Predictions.
2. 1304 : 426-427. Weather Maps.
 - a. 1102 : 318-333. Weather Observations in the United States.
 - b. 1301 : 102-104. Weather Maps.

- c. 1302: 279. Private Weather Observations.
- d. 1303: 81-82. Weather Predictions.
- e. 1307: 264-266. Weather Forecasting.
- f. 1309: 237-238. Weather Forecasts and the Weather Maps.
- g. 1310: 402-430. Weather Maps.
- h. 1311: 246-247. The Mapping of Temperature.
- i. 1312: 390-393. Weather Maps.
- 3. Weather Bureau. Explanation of the Weather Map.
Reprints from Yearbook of Department of Agriculture.
- 4. 1900. Amplification of Weather Forecasts.
- 5. 1906. New Problems of the Weather.
- 6. 1907. The Weather Bureau and the Public Schools.

Experiment 56. — Temperature Curves.

Apparatus: Thermometer.

Materials: Cross-section paper. (Sections about $\frac{1}{4}$ inch square.)

- a. Take thermometer home and record readings of temperature every hour from 7 A.M. to 8 P.M.
- b. Place the cross-section paper with the long side next to you and mark off the hours on every other line beginning with 6 A.M. and ending with 9 P.M. On the left side of the paper mark off the temperatures, beginning at a temperature 5° below the lowest reading which you took. Use one square for each degree. On the 7 A.M. line make a cross opposite the reading for that time. Use the same method for successive hours. Now run a *smooth* curve through all of the crosses, and the temperature curve is finished.
- c. What was the temperature at 9.30 A.M.? Obtain the information from your curve. This is an example of *interpolation*. What was the temperature at 6 A.M.? Extend the curve in the way in which it would seem to go naturally. This is an example of *extrapolation*.

108. WEATHER AND CLIMATE

The condition of the atmosphere for any particular day is the weather of that day. The average of the weather for the whole year is the climate of a particular locality. The climatic conditions are the sum total of all the weather conditions which take place in the year, and govern, to a great extent, the suitability of the locality for agricultural purposes or a place of residence. Persons do not realize what a great influence weather has upon human beings, and yet the studies of the United States Government are bringing those facts very strongly before the people of the United States at the present time. There are certain localities in which it is nothing less than suicide for some persons to live, and there are other localities which tend to develop bad traits of character in certain individuals, because of the continued physical discomfort they produce.

References:—

1. 1103 : 269-274. Weather.
2. 1103 : 293-312. Climate of the World.
3. 1304 : 275-279. Influences which Affect Climate.
4. Bulletin No. 311. Weather Bureau. Climate.
5. Bulletin No. 312. Weather Bureau. Invariability of our Winter Climate.
Reprints from Yearbook Department of Agriculture.
6. 1906. New Problems of the Weather.
7. 1908. The So-called Change of Climate in the Semiarid West.
 - a. 1101 : 85. Weather Defined.
 - b. 1102 : 333-334. Climate.
 - c. 1302 : 335-348. Weather and Climate.
 - d. 1303 : 74-81. Weather Changes.
 - e. 1303 : 82-85. Climate.

- f. 1305: 292-295. Weather and Climate.
- g. 1308: 99-100. Climate and Factors of Climate.
- h. 1309: 210-217. Weather and Climate.
- i. 1310: 440-461. Climate and the Determination of its Zones.
- j. 1311: 268-270. Weather and Climate.
- k. 1312: 388-390. Weather and Climate.
- l. 1312: 394-395. Changes in Climate Questioned.
- m. 1313: 171-175. Weather and Climate.

109. WEATHER INSTRUMENTS

It is desirable, for many reasons, to measure the factors which go to make the weather, such as rainfall, temperature, wind velocity and direction, humidity, atmospheric pressure, and sunshine. The different pieces of apparatus used for this purpose are called *weather instruments*.

The *rain gauge* collects the water which falls in a measured area, and the thickness of the layer of rain which fell is easily computed, or even measured.

Temperature is measured by a metallic thermometer which records its readings on a moving cylinder of paper. Its name is *thermograph*. The recording barometer makes its record in much the same way, and is called a *barograph*.

Wind direction is indicated by a *weather vane*; its velocity by revolving hemispheres, called an *anemometer*.

Humidity is measured by the *dew-point apparatus* or by means of a *wet-bulb* thermometer. The drier the air, the greater the evaporation from the cloth around the wet bulb, and therefore the temperature of the bulb is reduced. Tables of relative humidity may be consulted for desired answers.

The *sunshine recorder* absorbs enough heat from the sunshine to close an electric circuit by means of expanding mer-

cury. The duration of sunshine may then be recorded electrically.

References:—

1. 1103 : 104-105. The Anemometer.
2. 1103 : 123-125. The Psychrometer and the Hair Hygrometer.
3. 1103 : 145. The Rain Gauge.
4. 1103 : 164. The Piche Evaporimeter.
5. 1304 : 420-425. Meteorological Instruments.
6. 1803 : 102-103. The Wet- and Dry-bulb Thermometer.
7. 1803 : 136-137. Maximum and Minimum Thermometers.
8. Bulletin No. 235 : 5-8. Weather Bureau. The Sling Psychrometer and the Dew-point Apparatus.
9. Bulletin No. 285. Weather Bureau. Measurement of Precipitation.
 - a. 1101 : 11-41. Weather Instruments.
 - b. 1302 : 398-404. Meteorological Instruments.

110. HOME-MADE WEATHER INSTRUMENTS

The United States Department of Agriculture in its Yearbook for 1907 published directions for constructing home-made weather instruments. Reprints may be obtained, free of charge.

References:—

Reprint from Yearbook Department of Agriculture.

1. 1907. The Weather Bureau and the Public Schools. Pages 272-274. Home-made Instruments.

Pupils should be encouraged to make these simple instruments at home and use them.

111. THE OCEAN

The ocean occupies about three fourths of the surface of the earth, varying in depth from a few feet to about five

miles. It is an interesting fact that the highest mountain peak is about five miles above sea level, so that the largest variation in the surface of the earth is about ten miles. Water in large masses affects the climate of a locality to a very marked degree. It acts as a sort of balance wheel to the temperature, retarding its rapid rise as well as prolonging the warmth far into the winter time. We learned, under Convection of Heat, that a whole mass of water must be warmed before we can raise any part to a high temperature. We also learned that it takes more heat to warm water than any other substance, and that, having become warm, water stays warm longer than any other substance. It is quite probable that if it were not for the ocean, the earth would become unbearably hot, and also it is quite likely that during the cold weather the temperature would fall far below that at which life can be maintained.

The ocean serves as a pathway for trade, and a country is fortunate which has a long coast line with many inclosed bays and harbors. Transportation by ocean is necessarily cheaper than by rail, because there are no roadways to maintain, and in the case of sailing vessels there is no expense for power. See Section 202, Nature and Business.

On account of the mobility of water, storms at sea become much more dangerous than storms on land, for the water is picked up, forming large billows, which, by reason of their mass, may overwhelm and destroy the vessels; and the wind, having an unimpeded pathway, blows much more fiercely on the open ocean than on the land.

The ocean, because of its unlimited supply of fish of all kinds, is a never failing source of income to those who make fishing their business. Thus it is that we are dependent upon the ocean in more ways than are at first manifest.

References:—

1. 1103: 296-299. The Effect of the Ocean on Climate.
2. 1304: 277. Influence of Water.
 - a. 1302: 244-249. The Oceans.
 - b. 1303: 96-98. The Forms and Exploration of the Ocean.
 - c. 1305: 109-121. The Sea.
 - d. 1309: 192-199. Ocean Currents; their Causes and Effects.
 - e. 1310: 492-495. Composition of Sea Water.
 - f. 1311: 279-290. The Ocean.
 - g. 1312: 169-196. The Ocean.

112. PURIFICATION OF WATER

Water is purified by nature, and also by man, who employs the same methods. In fact, it should be clearly comprehended that man can make use only of natural phenomena in any of his work. All he can do is to control these phenomena within certain limits.

Water evaporates from the surface of the ocean, or other bodies of water, and from the land, to form water vapor, which condenses again to water. Only pure water evaporates. This is nature's method of distillation. Man distills water in a still. See Section 27, Distillation of Liquids.

Some rocks are very porous and allow water to pass through, but prevent solid matter from passing. Man uses a filter composed of some porous material, such as cotton, charcoal, sand, or unglazed clay. The latter is often in the form of a cylinder, the filtered water passing into the cylinder and leaving the dirt on the outside, whence it can be easily removed. This is the Pasteur filter.

Some chemicals may be held in solution and cannot be removed by a filter. See Section 115, Solution and its Effects. Chemical means may then be employed instead of

distillation. Usually a chemical can be added which will form an insoluble compound with the chemical which the water contains. This produces a precipitate which can be removed by filtration, or by sedimentation.

Bacteria and sewage may be removed by passing air into the water and by the effects of sunlight. Nature effects this result in waterfalls and rapids. Water cooled just to the freezing point is comparatively pure. Boiling will kill the bacteria, but will not remove the poisons which the bacteria have produced.

There may be substances in water which have a lower boiling point than water. If so, they must be distilled off first, and thus removed before the water itself is distilled. Finally, there may be poisons in the water which cannot be removed by an feasible means. See Section 196, Water Analysis.

References:—

1. 1501 : 137. Purification of Water.
2. 1702 : 64-65. Methods of Improving Drinking Water.
3. 1703 : 45-47. Purification of Water.
- a. 1701 : 50-54. Purification of Water.
- b. 1704 : 28-33. Purification of Water.
- c. 1706 : 39-40. Purification of Water.
- d. 1707 : 69. Purification of Water.
- e. 1708 : 268-270. Purification of Water.
- f. 1709 : 302-323. Purification of Water by Chemical Means.
- g. 1711 : 2-3. Preparation of Pure Water.
- h. 1801 : 281-282. Distillation.
- i. 1804 : 287-288. Distillation.
- j. 1808 : 234-235. Distillation.

Experiment 57. — Precipitation and Filtration.

Apparatus: Ring stand, burner, asbestos mat, evaporating dish, test tubes $6'' \times \frac{3}{4}''$, funnel, filter paper.

Materials: Hydrochloric acid, 1-4; common salt, silver nitrate solution, 5 per cent; sulphuric acid, 1-6; copper sulphate solution, 10 per cent; barium chloride solution, 5 per cent; ammonium sulphide, 10 per cent; lead nitrate solution, 5 per cent.

a. Dissolve some salt in a little water and taste it. Filter and taste. Did the salt pass through the filter paper? Put the salt solution in the evaporating dish, on the asbestos mat, and boil slowly to dryness. How does the amount of salt compare with the original amount? If sand and sugar became mixed, how could you separate them?

b. Take a teaspoonful of silver nitrate solution and filter it. Does anything remain on the filter paper? Now add a few drops of hydrochloric acid, and filter. The acid has changed the silver nitrate, which is soluble, into the insoluble silver chloride. There is no more silver in the solution. Repeat, using a solution of salt in the place of hydrochloric acid. Silver nitrate, then, is a test for a chloride.

c. Try the effect of the solution of barium chloride upon solutions of copper sulphate, and sulphuric acid. Note that the addition of hydrochloric acid produces no effect. If barium chloride produces a white precipitate in any liquid, in the presence of hydrochloric acid, it indicates that there was a sulphate present.

d. Try the effect of ammonium sulphide upon a solution of lead nitrate. Try the effect of lead nitrate upon a solution of ammonium sulphide. Each is a test for the other. A solution of lead nitrate is a test for the presence of any sulphide.

113. SPRINGS AND STREAMS

Streams may have their source from mere surface water which collects in the valleys, or, as is more often the case, from water which comes from beneath the earth and forms what is called a spring. The water seems to come upward, but in reality it is actually flowing downward from some higher place. Springs, as a rule, contain comparatively pure water, but there are many mineral springs which are used for medicinal purposes. These latter contain various minerals dissolved in the water, and are often very powerful in their action upon the human system, and even harmful, if taken in excess.

The water of rivers is usually not as pure, for surface drainage carries much foreign matter into them, and a river, free from waterfalls and rapids, soon becomes contaminated with all sorts of refuse matter, and even disease germs. Very often sewage of cities empties into rivers, rendering them unfit for domestic purposes, unless purified by some of the methods given in the preceding section.

References: —

1. 1205: 41-42. Wells and Spring Water.
2. 1304: 50-51. Rivers.
3. 1601: 179-180. The Effect of Atmospheric Pressure on Springs.
4. 1702: 59-64. Mineral Waters and Wells.
5. 1703: 43-45. Natural Water and its Impurities.
6. 1710: 62. River and Spring Water.
7. 1901: 222-224. Water and Disease.
 - a. 1206: 145-150. Springs and Artesian Wells.
 - b. 1209: 79-83. Springs, Mineral and Thermal, and Wells.
 - c. 1305: 195-201. Springs and Artesian Wells.

- d.* 1305 : 205-206. Streams.
- e.* 1306 : 228-230. Springs and Artesian Wells.
- f.* 1309 : 41-43. Hot Springs and Geysers.
- g.* 1311 : 100-104. Mineral Springs, Geysers, and Wells.
- h.* 1312 : 51-52. Spring Deposits.
- i.* 1902 : 135-136. The Contamination and Purification of Streams.

114. COMPOSITION OF WATER

For a long time water was considered as an element and not a compound as we now know it to be. In Section 66, Chemical Effects of Electricity, we learned that water could be separated into two parts of hydrogen and one part of oxygen, both by volume. It can be shown that the same proportion of hydrogen and oxygen may be mixed and exploded, producing nothing but water. Also, hydrogen may be burned quietly with the same result, without the explosion. See Section 1, Explosions.

Hydrogen, as a word, means "water producer." It is very useful for obtaining high temperatures, since the flame of hydrogen, burned in oxygen, is the hottest known flame. If such a flame impinges upon a stick of unslaked lime, the lime-light, sometimes called the calcium light, is produced. The light nearly all comes from the intensely hot piece of calcium oxide, or lime, which does not burn or fuse. Hydrogen is the lightest gas and is used to fill balloons where great lifting power is desired.

References: —

- 1. 1702 : 56-57. Chemical Composition of Water.
- 2. 1703 : 38-39. Nature of Water.
 - a.* 1701 : 40-42. Composition of Water.
 - b.* 1704 : 24-26. Composition of Water.
 - c.* 1706 : 50-58. Composition of Water.

- d. 1707: 59-65. Composition of Water.
- e. 1708: 266-267. Water and Its Composition.
- f. 1711: 6-10. Composition of Water.

Experiment 58. — To Prepare Hydrogen.

Apparatus: Test tube 8" × 1", rubber stopper with two holes, thistle tube, evaporating dish, ring stand, asbestos mat, burner; otherwise the same apparatus as in Experiment 3.

Materials: Granulated zinc, hydrochloric acid, 1-4.

a. Put a few pieces of zinc in the test tube and cover them with water. Insert the stopper, placing the thistle tube so that it reaches below the surface of the water in the tube. The delivery tube should be in the other hole. Fill bottles as in the Oxygen experiment. Add acid to the zinc through the thistle tube, and collect four bottles of hydrogen. Keep the bottles bottom side up; otherwise the hydrogen will escape.

b. Light the hydrogen in one bottle, and describe its combustion. Does hydrogen support the combustion of wood?

c. Place the mouth of a bottle filled with air against the mouth of a bottle filled with hydrogen, and invert them several times. Bring the mouths of the bottles near a flame. What happens? Why?

d. Turn a bottle of hydrogen right side up and try to light it after one minute. What is the result? Explain.

e. Boil to dryness the liquid from the hydrogen generator. It is zinc chloride. Expose the dried salt to the air, and tell what happens.

EXPERIMENT FOR THE TEACHER

The Philosopher's Lamp

Use a generator similar to the above, but in the place of the delivery tube insert a tube which has been drawn out to form a fine tip. After adding the acid, collect some of the hydrogen

in an inverted test tube. If this explodes, collect successive tubes until the hydrogen so collected burns quietly. Then light the hydrogen at the tip. The yellow color of the flame is due to the sodium in the glass.

Hold beaker of water, which is dry on the outside, but filled with cold water, in the flame, and notice the large amount of water which collects from the combustion of the hydrogen. This also proves that water is composed of hydrogen and oxygen.

115. SOLUTION AND ITS EFFECTS

We are inclined to think of solution as the disappearance of a solid within a liquid. While this kind of solution is most common, it is better to look upon solution as the uniform mixture of the particles of one substance throughout the particles of another substance. We can have a solution of a gas within a gas, called *diffusion*; of a gas within a liquid, called *absorption*; a gas within a solid, called *occlusion*; of a liquid within a liquid, called *diffusion*; of a liquid within a solid, called *water of crystallization*; and of a solid within a solid, called *alloy*.

If a solid is dissolved in a liquid, the boiling point of the liquid is raised, while the freezing point is lowered. Thus the addition of common salt to water enables a cook to boil the food at a slightly higher temperature, which may be desired in some cases. Likewise, the addition of salt to ice produces a mixture which has a lower temperature than the ice alone. The salt causes the ice to melt, and the necessary heat is taken from the solution. The latter does not freeze on account of the salt.

Platinum absorbs hydrogen so rapidly that the friction of the molecules as they enter the platinum is sufficient to raise the hydrogen to its kindling temperature. Automatic gas

lighters, cigar lighters, and the burning points of pyrographic instruments receive their heat from the absorption of hydrogen, or compounds of hydrogen, by platinum.

A solid is said to be insoluble when less than one part is dissolved in 1000 parts of the solvent, while it is called soluble if one part can be dissolved in 100 parts of the solvent. As a rule, solids are more soluble in hot than in cold liquids. The solution of solids usually lowers the temperature of the solvent.

References:—

1. 1501 : 22. Water and Solution.
2. 1703 : 58-63. Solution and its Effects.
3. 1803 : 121-124. Solution and Crystallization.
 - a. 1607 : 38-39. Solution of Solids.
 - b. 1611 : 55-59. Plant Food in Soil Water.
 - c. 1701 : 94-99. Solution.
 - d. 1704 : 30-31. Solution.
 - e. 1706 : 41-48. Solution.
 - f. 1707 : 70-72. Water as a Solvent.
 - g. 1709 : 40-45. Water and Solution.
 - h. 1711 : 12-20. Solution.
 - i. 1805 : 117. Solution.
 - j. 1807 : 191. Heat of Solution — Freezing Mixtures.
 - k. 1808 : 29. Solutions.

Experiment 59. — Solution and its Effects.

Apparatus: Ring stand, asbestos mat, burner, thermometer, beaker, 100 c.c., platinum wire No. 30, 5" long, forceps.

Materials: Common salt, ammonium nitrate, ice.

a. Warm some water in the beaker. Note the bubbles of air which come out of the solution.

b. Boil the water, and obtain its temperature. *While still heating* add a little salt, and note the change of temperature. Continue to add salt until the maximum temperature is reached. How much is it?

c. Take some cold water and add ice to it. What is its temperature? Add some salt, and record the lowest temperature which you can obtain.

d. Take some ice water, remove the ice, and add some ammonium nitrate. What was the lowest temperature which you obtained?

e. Take some cracked ice and add ammonium nitrate to it. What was the lowest temperature obtainable?

f. If there is gas in the laboratory, hold the platinum wire coiled into a small spiral, by means of the forceps, in the gas flame. Shut off the gas and turn it on again with the platinum still in the gas. The gas should ignite.

116. USES OF WATER

Water is used for drinking, cleansing, and agriculture. Aside from drinking purposes, water owes its usefulness to the fact that it readily dissolves many substances. Thus in cleansing, water and soap dissolve the dirt, while in agriculture water holds in solution the plant food which comes from the soil. See Section 115, Solution and its Effects. In Section 208, Simple Household Remedies, we will take up a consideration of drinking water, while in Section 196 we will study the analysis of water. Section 146 treats of the importance of water in agriculture.

On account of its mobility and noncompressibility, water is useful as a means of conveying pressure which may be utilized in water motors and hydraulic elevators. Waterfalls can be used to turn wheels and produce mechanical energy, which may be changed into electrical energy capable of being used at a great distance.

Water is taken as the standard of density, and the density

of any material, referred to water as a standard, is called its *specific gravity*. The specific gravity of any material may be obtained by finding the buoyant force which the water exerts upon it, when it is entirely submerged. The total weight of a body, divided by the loss of weight in water, gives the specific gravity of the body. The specific gravity of a liquid may be learned by dividing the loss of weight of a body of known weight, when immersed in a given liquid, by the loss of weight of the same body, when immersed in water.

References: —

1. 1501 : 135-137. Drinking Water.
2. 1503 : 19. Water in Living Things.
3. 1601 : 155-156. Amount of Water Used by Crops.
4. 1605 : 67. Importance of Water.
5. 1710 : 61-64. Water.
6. 1803 : 48-50. The Hydraulic Elevator and City Water Supply.
7. 1803 : 51-52. The Principle of Archimedes.
 - a. 1606 : 47-51. Why Moisture is Important.
 - b. 1701 : 55. Uses of Water.
 - c. 1704 : 21-23. Uses of Water.
 - d. 1705 : 161-162. Water.
 - e. 1706 : 31-38. Water in Nature.
 - f. 1711 : 1-2. Water and its Occurrence.
 - g. 1712 : 60-61. Uses of Water.

Experiment 60. — Specific Gravity — Buoyancy.

Apparatus: Platform balance on a stand, and set of weights, battery jar, 6" \times 8", pieces of iron, lead, glass, aluminum, and blocks of wood.

a. Weigh the piece of iron in air, and then weigh it while it is entirely submerged in water. Subtract this last weight from its weight in air. This is the loss of weight and is due to the buoyant force of the water, and is equal to the weight

of the water displaced. To obtain the specific gravity of iron, divide the weight in air by the loss of weight.

b. Repeat the above method, using lead, glass, and aluminum.

c. Float the block of wood and estimate how much of it is below the surface of the water. The amount below water divided by the whole thickness of the block will give the specific gravity of any floating body.

117. SURFACE TENSION

In Section 39 we learned that universal gravitation acts not only between every two bodies, but also between every two particles of any one body. We would expect, then, that matter would contract until it became a solid mass with no space between the molecules. This would happen if it were not for heat, which is molecular motion. The effect of contraction, however, is visible on the surface of liquids, either in films or in drops. The manifestation of this attraction is called *surface tension*, meaning the pulling together of the surface.

On account of surface tension any liquid which is freed from gravity, or is moving as fast as gravity can make it move, assumes the spherical form, as in the case of raindrops or shot. Shot is made by pouring melted lead from the top of a shot tower and receiving the lead drops in water, which prevents deformation. The circle is the figure which contains the greatest area with the least perimeter, while the sphere is the solid which contains the greatest amount of material with the least surface. For that reason shot and raindrops assume the spherical form due to their surface tension. Soap bubbles

tend to become smaller, if left on the pipe, because the surface contracts and drives out the contained air.

The attraction between the molecules of one body is called *cohesion*; that between the molecules of different bodies is called *adhesion*. In order that a liquid may wet another body, adhesion must be stronger than cohesion. Bugs and water spiders can walk on water because the force of cohesion of the water molecules is greater than the force of adhesion between the water and the feet of the spiders. On the other hand, if water wets an object, it produces the same effect as a very weak glue; that is, stickiness.

Warming a liquid increases the motion of the molecules and thereby weakens the surface tension. Dissolved substances also weaken surface tension.

References: —

1. 1601 : 72-73. Surface Tension in Soils.
2. 1803 : 113-116. Surface Tension.
 - a. 1607 : 36-37. Surface Tension.
 - b. 1801 : 99-101. Surface Tension.
 - c. 1802 : 26-28. Surface Tension.
 - d. 1804 : 134-135. Surface Tension.
 - e. 1805 : 121-122. Surface Tension.
 - f. 1806 : 57-61. Surface Tension. Oil on Water.
 - g. 1807 : 151-153. Surface Tension.
 - h. 1808 : 110-112. Surface Tension.
 - i. 1809 : 99-100. Surface Tension.

Experiment 61. — Surface Tension.

Apparatus: Glass tumbler, mosquito netting and cardboard, each 4" \times 4", medicine dropper, cake pan 8" \times 12", funnel.

Materials: Alcohol, camphor, small chip of wood, soap.

a. Fill tumbler full of water, lay the piece of mosquito netting on top of the water, and the card upon the mosquito

netting. Carefully invert and remove the card. The water should stay in the glass. Compare Experiment 42. Why does not the water come through the holes in the netting?

b. Hold the glass over the sink, and with a curved medicine dropper place a few drops of alcohol on the netting. Tell and explain what happens.

c. Place the little chip of wood upon the water in the cake pan and carefully deposit one drop of alcohol at one end of the chip. Tell and explain what happens. Fill the pan with fresh water, wash the chip, and replace it on the water. Then put a small piece of camphor at one end of the chip so that the camphor is in contact with the water. Describe and explain the result.

d. Use the funnel as a bubble pipe, and blow a soap bubble. Stop blowing and watch the bubble. Why does it contract? When it becomes straight across the large end of the funnel, what happens? Explain.

118. CAPILLARITY

Capillarity consists of those effects of surface tension which are manifested in tubes. If one end of a tube of small diameter, open at both ends, is placed in water, the water will rise in the tube above the surface of the outside water. The reason for this is as follows: the force of adhesion between the water and the glass is stronger than the force of cohesion between the water molecules, and the water creeps up the walls of the tube. Immediately the surface of the liquid within the tube contracts, on account of surface tension, and pulls up the rest of the water in the tube. This action continues until the weight of the water in the tube equals the force of adhesion. The smaller the tube is, the higher the water rises.

Examples of capillarity are everywhere present. Blotting

paper, mops, and lampwicks are common instances, while plants and the soil furnish other examples which may be less understood. The stalks of plants are composed of fine tubes, while the texture of the soil is such that there are countless microscopic passages in it through which water can pass. See Section 164, Plant Stems, and Section 147, How Water is Held in the Soil.

Some chemical substances crystallize, leaving capillary passages through which more of the solution may pass. The result is that the material will creep out of the dish in which it has been placed. Ammonium chloride, commonly called sal ammoniac, is the best example of a creeping salt.

References: —

1. 1605 : 85. Movement of Water in Soil.
2. 1702 : 240-241. Capillarity in Plants.
3. 1803 : 116-121. Capillarity.
4. Farmers' Bulletin No. 266 : 7. Movement of Water in Soils.
5. Farmers' Bulletin No. 408 : 40-41. Capillarity.
 - a. 1606 : 48. Capillary Water.
 - b. 1607 : 161-174. Capillary Movements of Soil Moisture.
 - c. 1612 : 41. Capillary Water.
 - d. 1801 : 101-103. Capillary Phenomena.
 - e. 1802 : 28-30. Capillary Action.
 - f. 1804 : 133-137. Capillarity.
 - g. 1805 : 123-124. Capillarity.
 - h. 1806 : 61-62. Capillary Action.
 - i. 1807 : 153-155. Capillarity.
 - j. 1808 : 112-114. Capillarity.

Experiment 62. — Capillarity.

Apparatus: Beaker 250 c.c., two beakers 100 c.c., several glass tubes of different internal diameter, lampwick, crystallization dish 5" diameter, ring stand, asbestos mat, burner.

Materials: Ammonium chloride.

- a. Stick several of the capillary tubes into water, side by side. How does the height of rise of water compare with the diameters?
- b. Take two tubes of the same internal diameter, and place one in cold water, the other in boiling hot water. Carefully compare the heights of the two columns. What are your conclusions?
- c. Fill the large beaker with water, wet a lampwick and bend it over the edge of the beaker, so that the longer end is outside. Place the beaker in the crystallization dish, and leave for a day. Compare the results with those of Experiment 45. Why is it not necessary to start the action in this experiment?
- d. Make a saturated solution of ammonium chloride, fill the small beaker half full, and set away, for a few days. Describe the result.

119. OSMOSIS

All gases, liquids, and solids tend to diffuse, and, if the diffusion is hindered, a pressure proportional to the diffusion tendency is produced. If two liquids are separated by a membrane which hinders the passage of one of the substances, a difference of pressure is manifested. The process is called *osmose*, and the pressure is called *osmotic pressure*.

Osmose takes place naturally in seeds and roots, the surfaces of which allow water to enter, but do not allow the material inside to pass out. Thus the beginning and the growth of plants are dependent upon osmose. See Section 163, Plant Roots, and Section 168, Fruits and Seeds. The swelling of beans, when "put to soak" is due to osmose, or, as it is more often called, osmosis.

Pieces of bladder, or any animal tissue, such as gold beater's

skin and skin of an egg, also show this same effect. In addition to the vegetable and animal membranes, there is one chemical membrane which is especially useful for showing osmotic pressure. This is formed by the combination of copper sulphate and potassium ferrocyanide to produce copper ferrocyanide. If this compound is formed within the pores of an unglazed earthenware cup, a strong semipermeable cell is obtained.

References: —

1. 1407 : 36-39. Osmosis in Plants.
2. 1503 : 78. Expansive Force of Germinating Seeds.
3. 1601 : 147-153. Osmosis and Diffusion in Plant Feeding.
4. 1605 : 65-66. Osmosis.
5. 1702 : 241-242. Osmosis in Plants.
6. 1703 : 132-133. Osmotic Pressure.
7. Farmers' Bulletin No. 408 : 13-15. How Roots Absorb Moisture.
 - a. 1607 : 41-48. Osmosis.
 - b. 1611 : 2-4. The Way the Seed Gets Water from the Soil.
 - c. 1612 : 47-48. Roots Take Nourishment by Osmosis.
 - d. 1707 : 447-448. Osmotic Pressure.
 - e. 1801 : 20. Osmosis.
 - f. 1805 : 117-118. Osmosis.
 - g. 1808 : 116. Osmose.
 - h. 1809 : 92. Osmose of Gases.

Experiment 63. — Osmotic Pressure.

Apparatus: Bottle, 6 oz., with stopper, string, porous cup 4" \times 2", stopper to fit, with one hole, glass tube $\frac{1}{8}$ " diameter, 4' long, battery jar 6" \times 8".

Materials: Beans, copper sulphate, potassium ferrocyanide, sugar.

a. Fill the bottle with beans, and then fill the spaces with water. Stopper the bottle tightly, and tie in the stopper. It

may be well to wrap the bottle with string. Leave until next day, and explain the result.

b. It is advisable to make all of the osmotic pressure cells at one time, or the teacher may make only one and show its action to the class.

Make a saturated solution of copper sulphate and a saturated solution of potassium ferrocyanide solution. Fill the porous cup with the potassium ferrocyanide solution, *wait five minutes*, and then place the porous cup in the copper sulphate solution. The two solutions will then meet somewhere within the walls of the porous cup. Leave for half an hour. Save the solutions.

Fill the osmotic cell (porous cup) with a saturated solution of sugar, insert the long tube in the stopper, and push the stopper firmly into the porous cup so that the solution runs a few inches up the tube. Now set the osmotic cell in the battery jar and fill the jar until the water stands at the same level as the sugar solution in the tube. If the osmotic cell is good, the solution will rise in the tube. If it does not do so, remake the cell.

120. *REMOVAL OF GREASE SPOTS AND STAINS*

For the removal of stains we have at our command three methods: solution, capillarity, and chemical action. The method to be employed must be determined by its effect on the material which is being cleaned. For that reason the use of chemical action is somewhat limited, while some solvents affect dyes.

To remove grease by solution, use ammonia water, gasoline, naphtha, benzine, alcohol, or ether. Ether is the most expensive, but it can dissolve some substances better than any other solvent.

To remove grease by capillarity, place a cloth or blotting paper *under* the goods, cover the goods with paper, and press with a moderately hot flatiron. Heat weakens surface tension, and the grease, after melting, moves *away* from the iron.

Pitch, gums, shellac, rubber, and cement may be dissolved by the same solvents, except ammonia water, as were used in the removal of grease. Carbon bisulphide is most useful for rubber. To remove pitch or other sticky gums from the hands, use kerosene.

Ink spots should have salt put on them at once. Then they may possibly be removed by warm water. If this has no effect, use lemon juice, and finally a 10 per cent oxalic acid solution. This is a poison. Remove the oxalic acid by washing immediately in water. Red ink may be removed by ammonia water or ether.

Plaster can be removed from floors and baseboards by means of hydrochloric acid, 10 per cent solution.

Paint may be removed by turpentine or benzine.

Iron rust may be dissolved by a 5 per cent solution of hydrochloric acid. Dip the spot into a shallow dish, containing the acid, and then pour on some ammonia water to stop the action of the acid. Delicate fabrics will not stand this treatment. Lemon juice and salt should be applied, in this case, and the article be placed in the sunshine.

Reference:—

1. 1710: 93-96. Cleansing.

Experiment 64. — The Removal of Stains.

Apparatus: Beakers, evaporating dishes.

Materials: Pieces of cloth, 4" x 4", any grease, ink, paint, pitch, gasoline, benzine, kerosene, turpentine, alcohol, ammonia water, oxalic acid, 10 per cent, hydrochloric acid, 5 per cent.

a. Put some grease on four pieces of the cloth and try to remove it by gasoline, benzine, turpentine, and ammonia water. Arrange the solvents in the order of their rapidity of action.

b. Put some black and red ink spots on one cloth, and allow it to dry. Repeat with a second cloth, but try oxalic acid at once, on the black spot, and ammonia, or ether, on the red spot. After the first becomes dry, try to remove the spots by the same method. Should spots be removed at once?

c. Put paint on a cloth and allow it to dry. Put some more paint on another cloth and try to remove it, at once, with turpentine or benzine. Next day try to remove the dried paint. Conclusions?

d. Put some iron rust on a piece of cloth and try to remove it with the 5 per cent solution of hydrochloric acid. Do not remove the hydrochloric acid from the cloth, and note how rotten the cloth becomes after a week's time.

121. ACIDS, BASES, AND SALTS — NEUTRALIZATION

Science classifies matter according to its known effect upon certain other kinds of matter. One of these test substances is litmus, a vegetable product. Certain materials cause blue litmus to turn red; we call them acids: others cause red litmus to turn blue; those are named bases. When litmus turns red, we call it an acid reaction; if it turns blue, we call it an alkaline reaction. Phenolphthalein is another test. Acids have no effect on it, but bases turn it red, after which acids will remove the color.

Acids all contain hydrogen, which may be set free from some acids by means of metals. See Section 114, Composition of Water. Bases all contain at least one part of hydro-

gen and one part of oxygen. If an acid is mixed with a base, the hydrogen of the acid and the combination of hydrogen and the oxygen of the base combine to form water. The result is that both the acid and the base lose their characteristics, and a salt is formed. This can be obtained by boiling away the water. A salt, then, is the result of the combination of part of an acid with part of a base, water being formed at the same time. We call this action *neutralization*. Most salts do not affect litmus paper or phenolphthalein; that is, they are neutral.

Sometimes there is an excess of acid in a person's stomach, which can be shown by testing the saliva with litmus paper. Ordinary baking soda will neutralize the acid and "sweeten" the stomach. See Section 208, Simple Household Remedies.

Sour milk contains an acid which can be neutralized by baking soda. Carbon dioxide is set free from the baking soda as fast as neutralization takes place. Cream of tartar has acid characteristics, and for that reason is used with baking soda to set free the carbon dioxide. The bubbles of this gas cause the dough to rise.

The soil tends to become slightly acid on account of the excretions from the roots of plants. This acidity may be corrected by the application of lime. See Section 158, The Liming of the Soil.

References: —

1. 1503 : 93. Acid Reaction of Root Hairs.
2. 1702 : 72-77. Acids, Bases, Salts, and Neutralization.
3. 1703 : 95-98. Acids, Bases, Salts — Neutralization.
 - a. 1701 : 106-109. Acids, Bases, and Salts — Neutralization
 - b. 1704 : 58. Acids, Bases, and Salts.
 - c. 1705 : 28-29. Neutralization.
 - d. 1706 : 87-98. Acids, Bases, and Salts.

- e. 1707 : 126-127. Acids, Bases, Neutralization, and Salts.
- f. 1708 : 136-141. Acids, Bases, and Salts.
- g. 1709 : 116-120. The Action of Acids and Bases.
- h. 1711 : 125-127. Acids, Bases, and Salts.
- i. 1512 : 51-59. Acids, Bases, and Salts.
- j. 1713 : 100-101. The New Theory of Acids.

Experiment 65. — Acids, Bases, and Salts — Neutralization.

Apparatus: Ring stand, asbestos mat, burner, evaporating dish, stirring rod.

Materials: Sulphuric acid, nitric acid, hydrochloric acid, all 1-4, ammonium hydrate, sodium hydrate, potassium hydrate, sodium carbonate, sodium bicarbonate, hydrogen potassium tartrate (cream of tartar), all 10 per cent solutions, blue and red litmus paper, phenolphthalein solution.

a. Test with blue and red litmus paper the effect of all the materials, using the stirring rod to obtain a drop of each. Rinse the stirring rod in water after each test before making another test. Make a list of your results in two columns; call one red or acid, the other blue or alkaline.

b. Fill the evaporating dish one third full of sodium hydrate, and add a few drops of phenolphthalein. What color does it become? Put a piece of blue litmus paper and a piece of red litmus paper on the edge of the dish so that they touch the liquid. Add hydrochloric acid slowly until there is no effect on the red or blue litmus paper. If too much acid is added, add a little more sodium hydrate until there is neutralization. Then boil to dryness. Taste of the result. Do you recognize the taste? What is it?

c. Ask your teacher for a few pieces of litmus paper to take home. Test sour milk, add baking soda, and test again. Conclusions? Test vinegar, washing soda, and soaps.

122. HYDROSCOPIC AND EFFLORESCENT SALTS

When salts are crystallized out of a water solution, they contain a certain amount of water, by virtue of which they are able to take the crystalline shape. This is called the *water of crystallization*, and is a fixed amount for a given substance. The water of crystallization may be driven out by heat, sometimes quietly, and sometimes with tiny explosions caused by the expansion of the water when it turns to steam. The color of the crystal is lost and it becomes white, showing that the color is due to the arrangement of the molecules, rather than to any inherent characteristics. If a crystal loses its water of crystallization, when exposed to air, it is said to be *efflorescent*.

On the other hand, some substances attract the moisture of the air and form chemical compounds with it. These are called *hydroscopic salts*, and they may or may not be dry after the absorption of the water. If they become wet, they are called *deliquescent*. Ordinary lime, unslaked, is an example of a hydroscopic substance which remains dry, although absorbing a considerable quantity of water. Calcium chloride and zinc chloride are examples of deliquescent substances. See Experiment 58.

Since the absorption of the water vapor of the air is the opposite to evaporation, a little calcium chloride placed in the water of fire pails will prevent the water from evaporating.

Salts, when deprived of their water of crystallization, have no fixed shape and are called *amorphous*. Some amorphous salts are very hydroscopic. Molasses is an example of an organic compound which is quite hydroscopic.

References:—

1. 1601 : 252.	Hydroscopic Moisture.
2. 1703 : 53-54.	Water of Crystallization and Mechanically Inclosed Water.
3. 1703 : 55-56.	Efflorescence, Deliquescence, etc.
a. 1701 : 54-55.	Water of Crystallization.
b. 1706 : 46-47.	Efflorescence and Deliquescence.
c. 1707 : 56-57.	Water of Crystallization, Efflorescence, and Deliquescence.
d. 1708 : 154-155.	Crystallization, Efflorescence, and Deliquescence.
e. 1709 : 47.	Efflorescence and Deliquescence.
f. 1712 : 67-68.	Water of Crystallization, Efflorescence, and Deliquescence.

Experiment 66. — Efflorescence and Deliquescence.

Apparatus: Balance, set of weights, watch glasses.

Materials: Sodium carbonate crystals, sodium sulphate crystals, granulated calcium chloride, sodium hydrate (solid).

a. Weigh about 5 g. of sodium carbonate crystals on a watch glass, and expose to the air for twenty-four hours. Then weigh again. Do the same with sodium sulphate. Describe the results, and state your conclusions.

b. Perform a similar experiment with calcium chloride and sodium hydrate.

123. SOAP

Soap is made by the combination of organic acids with sodium hydrate (caustic soda) or potassium hydrate (caustic potash). The process of soap making may be considered as the neutralization of the hydroxide by the acid contained in the oil or grease. Glycerine is formed at the same time, and is usually saved. Sodium hydrate produces a hard soap, while potassium hydrate is used to manufacture soft soap.

The kind of soap produced depends upon the materials used and the care with which the soap is made. Good results can be obtained only from good material, and then only if care is exercised. When the hydroxide is completely "saponified" there is no free alkali and the soap is suitable for toilet purposes.

Cheap soaps are usually the most expensive, as the free alkali which they contain will destroy fabrics washed with them.

References: —

1. 1702 : 200-201. Saponification.
2. 1703 : 340-341. Soap.
3. 1710 : 96-103. Soap and Soap Powders.
 - a. 1701 : 410-411. Saponification.
 - b. 1704 : 226-230. The Manufacture of Soap.
 - c. 1705 : 156. Saponification.
 - d. 1706 : 422-423. Soap.
 - e. 1707 : 465-467. Soap and its Action on Hard Water.
 - f. 1708 : 206-207. Soaps and their Action.
 - g. 1709 : 387-389. Soap and Soap Making.
 - h. 1711 : 299-300. Oils and Fats — Soap.
 - i. 1712 : 300-302. Soaps and their Action.
 - j. 1713 : 19. Soaps, Medicaments, etc.

Experiment 67. — To Make Soap.

Apparatus: Ring stand, burner, iron dish.

Materials: Lard, sodium hydrate, 15 per cent solution, salt.

a. Take about 60 c.c. of the sodium hydrate solution, in the iron dish, and add about 25 g. of lard. Boil slowly for ten minutes, and then add, gradually, about 15 g. of salt. Continue to boil for a few minutes. Allow the whole to cool, and remove the soap, which will be on top of the mass. Let the cake dry for a few days, and then test its ability to produce suds.

- b.* Test your soap with litmus. Do you think that your soap would make a good toilet soap?
- c.* Soft soap may be made by using potassium hydrate and no salt. There is a great excess of the alkali in soft soap.

124. HARD WATER

Water is called hard or soft according to the ease with which soap forms suds in it. If water is rendered soft by boiling, it is called *temporarily* hard, and the hardness was due to calcium carbonate, which was dissolved in it. This calcium carbonate, or lime, is deposited on the bottom and sides of the teakettle. If tested with hydrochloric acid, it shows itself to be a carbonate. See Section 90, The Chemical Engine.

On the other hand, if the water is not changed by boiling, it is called *permanently* hard. In this case calcium sulphate or magnesium sulphate is present; both may be present. Permanently hard water can be rendered soft only by chemical means. Boiling alone has no effect on it. By the addition of soaps, chemical compounds are formed with the calcium sulphate, or magnesium sulphate, which are insoluble, and collect as a scum which may be removed. The softened water is not fit to drink, but is excellent for cleansing purposes. It must be remembered, however, that it is costly to use hard water, since the soap used to soften it is wasted as far as the real cleansing is concerned. For the testing of water, see Section 196, Water Analysis.

References: —

1. 1703:47. Hard and Soft Water.
2. 1710:67-68. Hard Water.
 - a.* 1701:309-310. Temporary and Permanent Hardness of Water.

- b. 1705: 56-57. Hard and Soft Water.
- c. 1706: 327. Calcium Compounds and Hardness of Water.
- d. 1707: 359-361. Temporary and Permanent Hardness.
- e. 1708: 268. Hard Water.
- f. 1709: 247-248. Hard Waters.
- g. 1712: 65-67. Soft and Hard Waters.

Experiment 68. — Temporary Hardness.

Apparatus: Kipp generator, test tube, test-tube holder, burner.

Materials: Marble in lumps, hydrochloric acid, calcium hydrate (limewater).

a. Fill a test tube half full of limewater, and pass carbon dioxide, from the Kipp generator, into it slowly. Tell what happens. Continue to pass in the carbon dioxide, and tell what happens.

b. Warm the contents of the test tube, and tell what happens. The heat causes the excess of carbon dioxide to pass off, and the calcium carbonate is no longer soluble. Thus heating water which is temporarily hard causes the dissolved material to be precipitated.

125. THE EARTH'S CRUST

We see agents of disintegration acting on the earth's surface, and by working backward we shall always be led to the realization that once all must have been solid rock, without any covering of soil. By analyzing soil, we find that it is merely changed rock, altered both physically and chemically, but containing the material which goes to make up the rock. Review Section 30, Chemical and Physical Changes.

Gradually the surface became covered with a thin soil which slowly grew thicker as the agents of erosion continued

to act. It must be remembered, however, that the thickness of the earth's crust is slight compared with its diameter, and that the interior of the earth is hot, and would, under ordinary conditions, exist in a liquid form, but does not at present, on account of the tremendous pressure which it bears. In deep mines the temperature is so high that it is impossible to work continuously more than a short time. See Section 48, *The Heat of the Earth*.

References: —

1. 1205 : 17-21.	Mantle Rock and the Soil.
2. 1304 : 16-22.	The Solid Earth.
a. 1201 : 19-22.	How the Rocky Crust was Hidden.
b. 1203 : 13-19.	The Decay of Rocks and the Causes.
c. 1209 : 16-17.	Weathering.
d. 1302 : 29-31.	The Earth Crust ; Mantle-Rock.
e. 1303 : 134-138.	Activities and the Wasting of the Land.
f. 1305 : 180-182.	The Structure of the Earth.
g. 1309 : 75-76.	Relief of the Land.
h. 1311 : 11-13.	Continuous Change.

126. CHANGES IN THE SURFACE OF THE EARTH

By "changes" is meant all those modifications of the surface which have taken place since the earth became cold enough to allow water to fall upon it, as well as the modifications which are taking place at the present time. The large changes, such as the formation of rocks, and the building of mountains, will be taken up under those headings. Now we are to consider those alterations, or modifications, which affect and have affected the surface itself; by "surface" is meant only the few upper feet of the earth. Refer to Section 139, *How Mountains are Made*, and to Section 133-137, which treat of rocks and their formation.

References:—

1. 1304: 18-19. Air, Water, Rock.
2. 1601: 27-28. The Origin of Soil.
- a. 1202: 150-154. Principles Involved in Rock Weathering.
- b. 1208: 10-23. Erosion by Air and Water.
- c. 1302: 29-32. The Earth Crust.
- d. 1307: 24-25. The Rock Mantle and its Movements.
- e. 1608: 24-28. The Source and Production of Soil.
- f. 1612: 1-4. The Earth's Clothing.

127. WEATHERING AND THE RATE OF WEATHERING

The changes which occur in the earth's crust, whether they be those of erosion or chemical changes, are all classified under one heading, *Weathering*. The earth is very different from what it was when it first cooled off, both in shape and in its surface features, as well as the character, or make-up, of its surface. We may classify these under Changes in the Surface of the Earth, Section 126, but for purposes of study they are taken separately. See Section 129, Erosion.

When it first began to rain, that is, when water could exist, even in the atmosphere of the earth, as a liquid, the enormous rainfall accomplished an erosion of the rocks which is incredible when we think of the effects of a modern rainstorm. Then, also, as the water wore off the surface of the earth, the material worn off formed a sort of protective covering, and thus the rate of weathering became less as time went on. Nevertheless, water still continues to produce more rapid results than any other single agent of weathering.

References:—

1. 1205: 5-38. The Work of the Weather.
2. 1304: 38-40. Weathering.
3. 1304: 41-42. Rate of Weathering.

- 4. 1601 : 9-15. The Atmosphere and its Work.
- 5. 1601 : 21-26. Over and Over Again.
- a. 1202 : 255-266. Rate of Weathering.
- b. 1203 : 13-19. The Decay of Rocks and the Causes.
- c. 1206 : 124-127. Difference in the Rate of Weathering.
- d. 1209 : 16-17. Various Rates of Weathering.
- e. 1301 : 254-257. The Effects of Weathering.
- f. 1302 : 210-224. Land Sculpture.
- g. 1303 : 136-139. The Wasting of the Lands.
- h. 1307 : 111. Weathering Processes.

128. AGENTS OF WEATHERING

Without doubt, rain produces the greatest visible change upon rocks and the soil, yet probably the action due to the air and to certain microbes accomplishes an amount not fully realized. The agents of weathering, then, are rain, and, in fact, water in all its forms,—for large masses of snow and ice accomplish work not possible to water alone,—heat and cold, the oxygen of the air, and various microorganisms, as well as some plants and trees.

We learned when we were studying heat that it causes the expansion of all material, and the expansion is pretty nearly proportional to the temperature. Where the sun shines on exposed rocks, their surface becomes hot much faster than their interior. This causes their surface to expand faster than their interior, making the outside of the rock too large to fit on the inside, so that there is a separation of a thin layer. When the rock becomes cool at night, the reverse action takes place. The outside contracts more rapidly than the inside, since radiation takes place from the surface. Then the outside is too small for the inside, and peels off. We call this *exfoliation*, and if we are on the watch, we may see many evidences of this action.

Extreme cold, where there is water present, is one of the greatest forces in weathering. When water freezes, it expands about one eleventh of its volume. Water is everywhere present in crevices and even within many rocks. Therefore, whenever cold weather comes, this water freezes, expands, and breaks the rock into countless numbers of pieces, for the expansive power of freezing water is almost irresistible. When warmer weather comes, the ice melts, runs out, carrying with it the smaller pieces of rock and leaving larger gaps behind for rain, the roots of trees, and burrowing animals, to enter. Water pipes, in cold places, are burst in a similar fashion.

Chemical changes are those which alter the make-up of matter in its finest divisions. On the surface of the earth oxygen is the most active in producing these chemical changes. Oxygen combines very readily with a large number of elements which compose the surface of the earth, and by its combination changes insoluble parts into other substances, which are readily soluble in water. Thus oxygen prepares the way for the action of the water, which is twofold: mere wearing away, and solution. Oxygen is especially active on iron compounds.

In organic compounds, that is, different compounds of carbon which have had life at some time, oxygen produces a decay, or aids in the decay started by certain bacteria which form various compounds with carbon and hydrogen. Therefore oxygen, working in conjunction with bacteria, tends to remove all dead vegetable and animal matter, and return its constituents either to the ground or to the atmosphere. Consequently the same material is used over and over again, in plant life and animal life.

References: —

1. 1205 : 13.	Oxidation.
2. 1205 : 13-15.	Effects of Heat and Cold.
3. 1304 : 13-14.	The Atmosphere in Relation to Decay.
4. 1304 : 44-45.	Agents of Erosion.
5. 1601 : 15-18.	Water and its Work.
6. 1601 : 18-21.	Living Forms and their Work.
a. 1201 : 119-121.	Work of Oxygen.
b. 1202 : 177-180.	Action of Freezing Water and Ice.
c. 1203 : 14-17.	The Causes of Decay in Rocks.
d. 1206 : 112-114.	The Effect of Heat and Cold.
e. 1208 : 30-40.	Igneous Agencies.
f. 1209 : 18-28.	Agents of Weathering.
g. 1302 : 57.	Weathering by Oxygen.
h. 1310 : 40-44.	Freezing and Thawing.
i. 1311 : 131-132.	The Glacier's Work,
j. 1312 : 262.	Disintegration of Rock through Heat.
k. 1604 : 18-28.	Effects of Weather upon the Land.
l. 1612 : 7-16.	Soil Makers.

129. EROSION

Erosion is, as has been stated, the most rapid factor in weathering, but it would not be so active if it were not for the work of the other factors. The work of running water, however, is very great. Deep valleys and cañons have been dug by moderate-sized streams, working during countless centuries; in other valleys lakes have been formed by some stoppage at the mouth of the river. The result of the water's work has been to carve our hills into their present state, for a large number of our mountains were really huge billows in the surface of the earth, until water cut some places deeper than others and gave us the rugged, cragged mountains.

References: —

1. 1205 : 56-60. Transportation and Erosion by Streams.
2. 1304 : 51-54. The Load of Rivers.
3. 1304 : 66-68. Alluvial Fans and Filling of Valleys.
4. 1601 : 15-18. The Work of Water.
- a. 1201 : 23-26. How Erosion Exposes the Rocks to our View.
- b. 1203 : 108-110. Rivers and the Making of New Land.
- c. 1301 : 257-260. Erosion of the Land.
- d. 1302 : 57-67. Erosion.
- e. 1303 : 245-249. Work of Rivers.
- f. 1303 : 256-261. Development of Valleys.
- g. 1305 : 181. Weathering and Erosion Defined.
- h. 1309 : 75. Erosion Defined.
- i. 1310 : 86-91. Erosion and its Effects.

130. AGENTS OF EROSION

Next to rain and rivers, the wind and the ocean waves are the most important agents of erosion. When the air moves with a certain rapidity, it picks up sand and small pebbles and hurls them against rocks and mountains, wearing them away. We may consider that the wind actually becomes a sand blast, each particle of sand and pebble becoming a sort of chisel, which cuts off a grain here and a grain there from the mountain side; but owing to the countless number of grains of sand, the work accomplished is sometimes very great. In sandy districts, telegraph poles and fence posts have been cut through by the action of the blowing sand.

There is another form of water erosion besides those mentioned which has a limited zone in which to work. This is the wear of the waves upon the beaches and cliffs which form the shore of the ocean. We have records in some instances where waves have removed large areas of land. On the other hand,

under proper conditions, the waves pile up deposits and produce new land. The waves work their way through rocks, forming caves and caverns. The water wears away the softer parts of the rocks, and does not affect the harder parts as much.

References: —

1. 1205 : 144-153. Wind Erosion.
2. 1205 : 156-161. Sea Erosion.
3. 1304 : 87-88. Wind Work on Deserts.
4. 1304 : 210-215. Wave and Tide Work.
 - a. 1202 : 280-286. Action of Wnd.
 - b. 1206 : 129-138. Wind Erosion.
 - c. 1209 : 182. Force and Work of Waves.
 - d. 1211 : 109-118. Wind Erosion.
 - e. 1302 : 229-232. Wave Action.
 - f. 1303 : 286-288. Wind Action in Deserts.
 - g. 1303 : 305-307. Work of the Sea on the Shore.
 - h. 1306 : 244-245. Ocean Erosion.
 - i. 1309 : 227-228. Surface Effect of Winds.
 - j. 1310 : 27-28. The Work of the Wind.
 - k. 1310 : 227-231. Erosion by Waves.
 - l. 1312 : 198-203. Shore Erosion.

**131. DISINTEGRATION DUE TO PLANT AND ANIMAL LIFE
— BACTERIA**

We are continually learning more about the effect of bacteria on all the changes which take place in matter. We know that they play a great part in the disintegration of rock and soil material, forming plant food in which vegetables may have their life. Bacteria aid in many chemical changes, especially those of decomposition, and probably aid in chemical reactions to a considerable extent. Later we will take up the study of bacteria under various headings.

Animals, in burrowing, leave holes through which tree roots may easily find their way when seeking water. These holes also allow water to enter, so that it may dissolve the lower soil material and later bring it to the surface.

The roots of plants penetrate far into the soil, and by their growth lift up large masses of ground. They even penetrate minute crevices in rocks, and, as they grow, actually split them apart, exposing more and more surface of the rocks to the action of the other agents of weathering.

References: —

1. 1205 : 20-21. How Humus and Subsoil are Mingled.
2. 1304 : 40-41. Organisms as Agents of Weathering.
3. 1601 : 18-21. Living Organisms and their Work.
 - a. 1206 : 116-117. Work of Burrowing Animals.
 - b. 1207 : 317-320. The Work of Burrowing Animals.
 - c. 1208 : 23-30. Organic Agents of Changes.
 - d. 1302 : 59. Plant and Animal Disintegration.
 - e. 1311 : 83-85. Effect of Animals on Soil.
 - f. 1312 : 262. Disintegration of Rocks by Plants.
 - g. 1508 : 153-154. The Usefulness of the Earthworm.
 - h. 1604 : 60-89. Field Laborers.
 - i. 1612 : 17-22. The Soils that Living Things have Made.

132. SLOWNESS OF CHANGE

When we consider the action of the various factors which have changed the surface of the earth, we must not lose sight of the vast, almost incalculable, period of time through which they have acted. Rocks have been formed through sedimentation, and have been pushed up by the contraction of the earth's surface. They have then been worn down by rain and running water, and have formed sand, which has passed to the ocean, to enter once more into the formation of rock. In

turn these rocks have been raised above the surface of the ocean to form new land. Plants have lived, borne fruit, died, decayed, become soil again, as food for other plants; animals have eaten of plant food and died and fertilized the ground for coming generations of plants. It is this continual change, which, acting through a length of time that is almost impossible for the human brain to conceive, has produced our present earth.

References: —

1. 1205 : 5. Slowness of Change.
2. 1304 : 42-44. Results of Weathering.
3. 1304 : 45-46. Age of the Earth.
4. 1601 : 21-26. Over and Over Again.
 - a. 1207 : 343-348. Results of Slowness of Change as Applied to Agriculture.
 - b. 1301 : 255. Slowness of Change.
 - c. 1312 : 270-273. The Geographic Cycle.
 - d. 1612 : 7-8. Slowness of Change.

133. ROCKS DEFINED AND CLASSIFIED

We call the material of which the earth is made, rock, and we may consider that the whole earth is made of rock. This rock has been changed through several kinds of processes into a large variety of sands, clays, and soils. The kinds of rocks which compose the surface of the earth are divided into several classes, according to the way in which they were formed. They are: sedimentary, chemically formed, organic, igneous, metamorphic, and æolian. In addition, there are various combinations of these rocks which cannot be classified.

On the surface of the earth rocks occur which are called *mantle rock* on account of being loose, and forming a mantle over the surface of the earth, while underneath is the

solid rock which constitutes the main part of the crust of the earth. This is called *bed rock*. Rock may be carried by streams and deposited in other places, where it has not previously formed a part of the earth, and this is called *transported rock*.

References : —

1. 1205 : 22-28. Movements of the Mantle of Rock Waste.
2. 1304 : 32-33. Rocks of the Earth's Crust.
3. 1601 : 38-43. Influence of Rock Structure in Soil Formation.
 - a. 1201 : 9-12. What the Earth is Made Of.
 - b. 1201 : 47-51. How Rocks are Made.
 - c. 1202 : 1-3. Definition and Occurrence of Rocks.
 - d. 1203 : 20-35. How Common Rocks are Made.
 - e. 1206 : 54. The Formation of Rocks.
 - f. 1208 : 68-71. Classification of Rocks.
 - g. 1209 : 4-11. Transportation and Deposition by Wind.
 - h. 1305 : 216-219. Transportation of Rock by Running Water.
 - i. 1307 : 27. Rock and its Structure.
 - j. 1308 : 36-37. Kinds of Rocks.
 - k. 1312 : 264-266. Mantle Rock.

134. THE DIFFERENCE BETWEEN MINERALS AND ROCKS

A rock is a combination of several minerals, usually less than four, and is a part of the earth's crust. A mineral is a definite chemical compound, existing in rock masses, or alone. Those minerals from which a desired element may be obtained easily are called *ores*.

References : —

1. 1205 : 286-290. Mineral Veins.
2. 1304 : 406-408. Common Minerals.
3. 1703 : 334. Minerals and Ores Defined.
 - a. 1201 : 107-109. Difference between Rocks and Minerals.

- b. 1202 : 1-3. Definition of Rocks.
- c. 1202 : 9-12. The Minerals Constituting Rocks.
- d. 1206 : 33-34. Minerals Have a Definite Chemical Composition.
- e. 1208 : 36-37. Rock, a Mixture of Minerals.
- f. 1209 : 192-193. Properties of Minerals.
- g. 1210 : 233-234. Mineral Veins.
- h. 1301 : 221-225. Minerals of the Crust.
- i. 1305 : 180-181. Minerals and Rocks.
- j. 1312 : 239-246. Minerals.

135. ROCKS OF THE EARTH'S CRUST

Sedimentary Rocks. — The rain washes pebbles, sand, and pieces of rock down from the hills; these are carried by rivers into lakes and the ocean, where they settle, forming layers along the bottom. The next time there is a heavy rush of water there will be another layer formed, and thus the material is built up, layer upon layer, until great depths have been filled. These layers are called *strata*, and the rock is said to be *stratified*. The thickness of the strata depends upon the amount of material which was brought down at one time. These strata are naturally horizontal where they have not been disturbed. We will study the result of their disturbance under the formation of mountains. As time goes on, the great pressure and the action of cementing material contained in some of the rocks cause these rock strata to become solidified into one huge rock mass, maintaining, however, the definite strata which went to make it.

Igneous Rocks. — Melted rock which has come up from within the earth may appear either on the surface, or may fill crevices and caverns below the surface. When cool, it is called *igneous rock*, receiving its name from the fact that it was once

very hot. If the cooling has taken place slowly, we have a crystalline structure, of which granite is an example. Where the cooling took place very rapidly, the same material produced what is called natural glass, or *obsidian*, having no structure whatever. Where lava is blown up by the expansion of steam, *pumice* and volcanic ash are formed.

Metamorphic Rocks. — Where rocks have been subjected to the action of earth heat, or great pressure, or both, certain changes have taken place in them. We call this *metamorphism*. Thus sandstones may become a solid mass of quartz, and shale change to slate. Coal, in some cases, has been changed to graphite, which is pure carbon. Under the effects of metamorphism, some minerals have been recrystallized, according to some other plan, and other rocks have had their nature entirely altered.

Chemically Formed Rocks. — Nearly all of this kind of rock is formed beneath the surface of the earth, although it does appear around geysers and hot springs. Some of the minerals through which water flows dissolve when the water is hot, and may impart carbon dioxide to the stream. As the water cools or loses its carbon dioxide, the dissolved material is deposited. This forms stalactites in caverns, calcareous tufa around the hot springs, and silica around the geysers of Yellowstone Park.

Æolian Rocks. — There is one other class of rocks which, because they have been caused by winds, are called *æolian*. The wind, picking up sand and pebbles, has blown them into hollows, and as the centuries went by has piled tons upon tons, which, on account of the pressure, and the presence of some cementing material, have finally formed solid rocks. Sand dunes may be considered under this head, although they are not compact.

References: —

1. 1205 : 147-151.	Wind Deposits.
2. 1205 : 180-186.	Stratification and the Rate of Deposition.
3. 1205 : 265-276.	Underground Structure of Igneous Origin.
4. 1205 : 281-283.	Metamorphic Rocks.
5. 1304 : 409.	Sedimentary Rocks.
6. 1304 : 411-412.	Igneous Rocks.
7. 1304 : 413.	Metamorphic Rocks.
8. 1601 : 68-69.	Wind-formed Soils.
a. 1201 : 53-55.	Three Kinds of Sedimentary Rocks.
b. 1202 : 55-61.	Igneous Rocks.
c. 1202 : 112-113.	Sedimentary Deposits.
d. 1202 : 133.	Æolian Rocks.
e. 1206 : 70-73.	Sedimentary or Stratified Rocks.
f. 1206 : 98-104.	Metamorphic Rocks and the Result of Metamorphism.
g. 1301 : 226-232.	Rocks of the Earth's Crust.
h. 1302 : 29-32.	Mantle Rock and Bed Rock.
i. 1306 : 238-239.	Wind Erosion.
j. 1307 : 29-32.	Sedimentary Rocks.
k. 1312 : 226-228.	Sand Dunes.

Experiment 69. — Sedimentation.

Apparatus: Student lamp chimney with stoppers to fit both ends.

Materials: Coarse gravel, sand, loam, and clay.

a. Mix equal parts of the materials to make enough to fill the chimney two thirds full. Fill rest of the space with water. Then stopper and shake vigorously. Allow the chimney to stand in an upright position until the water becomes clear. Describe the arrangement of the materials. Stratified rock was formed by the transportation of different materials in water, and the sedimentation, while slower, was similar to that which took place in the lamp chimney.

136. ORGANIC ROCKS

Wherever the word *organic* is used, it is to be understood that the material which "organic" describes once possessed life, either vegetable or animal. Many animals and shellfish get their supply for shells from the carbonate of lime which is dissolved in the water. When these animals die, their shells become compacted by pressure of one layer upon the other, and form limestone. Another factor which enters into the formation of rock is the diatoms, a very small plant which lives at the surface of the sea in warm climates, and has a shell-like covering containing silica. Large masses of the dead bodies of these settle to the bottom, likewise forming rock, which is called *diatomaceous*.

Coral islands are produced by the gradual accumulation of coral growth. Coral is an animal, growing in a shell, and the remains which we see are merely calcium carbonate with a few other compounds in very small amounts. An acid applied to coral, as well as to all of the organic rocks, except those containing silica, sets free carbon dioxide.

Diatomaceous rock is used for polishing purposes, since the little particles, although very fine, are sharp, and cut away the dirt or tarnished material. It is also used as a sound proofing for deadening sound in buildings, and as a packing for fire proofing and for cold-storage plants. Since it is a very poor conductor of heat, it is valuable for these latter purposes.

References: —

1. 1304 : 410-411. Organic Rocks.
2. 1503 : 202. Coral Reefs.
3. 1703 : 200-201. Natural Carbonates.
a. 1201 : 85-86. Diatomaceous Earth.

- b. 1201: 87-91. Limestone and Marble.
- c. 1202: 123-128. Diatomaceous Earth and the Carbonates.
- d. 1206: 89-96. Organic Rocks.
- e. 1208: 28-30. Formation of Limestone, Diatomaceous Earth, etc.
- f. 1209: 175-183. Geological Work of Marine Animals.
- g. 1311: 76. Limestone.
- h. 1312: 258. Calcareous and Carbonaceous Rocks.

Experiment 70. — To Test Rocks.

Apparatus: Medicine dropper.

Materials: Marble, coral, limestone, unknown rocks, soil, hydrochloric acid, 10 per cent.

- a. Using the medicine dropper, put a drop of acid upon each of the known rocks and note the bubbling or effervescence which indicates the liberation of carbon dioxide.
- b. Test the unknown rocks and the samples of soil. You can recognize the carbonates by this method.

Imitation coral is a porcelain and cannot be detected by sight or feeling. A drop of hydrochloric acid proves the true coral if bubbles of a gas are produced.

137. COAL, SOFT AND HARD

Another variety of organic rock is *coal*. In prehistoric times plants grew to an enormous size, so that the remains accumulated very fast, and there was a thick layer of decayed vegetable matter on the ground. On account of the great amount of rain, large swamps were formed. Vast layers of this decayed material subsided gradually and were subjected to the high temperature of the interior of the earth and the tremendous pressure, also, of the material on top of them. Under these circumstances, the mass lost its water and gases, and changed to coal. Where the process took place for a

short time, *lignite* was formed. After a longer time *bituminous* coal resulted, while *anthracite* coal is the result of complete change.

In *peat* bogs we have a form of very impure carbon, yet peat may be dried and burned. There are factories, also, where peat is ground up, mixed with petroleum, and then compressed into blocks. This produces an economical fuel.

Anthracite coal is almost pure carbon, and, if heated, gives off but very little gas. Therefore this coal burns almost without flame. See Section 10, Flames. Since the process of natural destructive distillation has not gone as far in the case of bituminous as of *anthracite* coal, the former sets free a large amount of gas when heated, and burns with a smoky flame. Bituminous coal is used to manufacture coal gas. See Section 28, Destructive Distillation.

Coal is not affected by acids, but is attacked quite vigorously by the oxygen of the air. This is especially true of bituminous coal, and spontaneous combustion often takes place in piles of coal where the ventilation is poor.

References: —

1. 1205: 352-354. How Coal was Made.
2. 1407: 341-342. Coal.
3. 1702: 48. Coal.
4. 1710: 28-29.
 - a. 1203: 226-230. Coal.
 - b. 1204: 38-45. The Coal-making Time in North America.
 - c. 1206: 460-463. How Coal was Made.
 - d. 1210: 301-311. Origin of Coal and its Varieties.
 - e. 1701: 199. Coal.
 - f. 1704: 168-169. Coal.
 - g. 1705: 186-187. Coal.
 - h. 1706: 184-187. Coal.
 - i. 1707: 183-184. Coal.

- j. 1708 : 90-92. Coal.
- k. 1709 : 228-230. Coal.
- l. 1711 : 272-273. Coal.
- m. 1712 : 256-259. Coal.

138. PETROLEUM AND NATURAL GAS

The source of petroleum and natural gas is organic matter, both animal and vegetable, which has accumulated in vast masses. This material subsided like the coal-producing material, and was subjected to tremendous pressure, together with very high temperature. By chemical change, and a process of natural distillation, this matter was changed to oil and gas, both of which have collected in large pockets. On account of the stratification of the rocks, an oil well must be drilled through certain layers until a pocket is reached. Then, if there is pressure upon the oil, due to its own weight or to gaseous pressure, the oil will gush or flow out; otherwise, pumps must be used to obtain it.

References: —

- 1. 1205 : 330-331. Petroleum and Natural Gas.
- 2. 1601 : 20. Origin of Mineral Oil and Natural Gas.
- 3. 1702 : 109-113. Petroleum and Mineral Oils.
- 4. 1703 : 411-412. Petroleum and Refining.
- 5. 1710 : 51-53. Distillates from Petroleum.
 - a. 1201 : 97-102. The Story of Petroleum.
 - b. 1203 : 230-231. Petroleum and Natural Gas.
 - c. 1204 : 219-222. Petroleum and its Products.
 - d. 1206 : 166-183. Liquid and Gaseous Sunlight.
 - e. 1208 : 82-84. The Relation between Coals and Bitumens.
- f. 1210 : 313-315. Petroleum and its Origin.
- g. 1306 : 425-426. Natural Gas and Petroleum.
- h. 1308 : 307-309. Petroleum and Natural Gas.
- i. 1706 : 207-209. Petroleum.

Experiment 71. — Distillation of Petroleum.

Apparatus: Hard glass test tube 8" \times 1", cork stopper, with one hole, to fit, glass tube $\frac{1}{4}$ " bent at right angles, four U-tubes having side tubes, cork stoppers to fit, rubber tubing to connect glass tubing and U-tubes, ring stand, burner, battery jar, 6" \times 8".

Materials: Crude petroleum.

a. Fill hard glass tube one fourth full of crude petroleum, and connect it to the U-tubes with pieces of rubber so that the distillates will have to pass through one after the other. Put the U-tube which is farthest from the heat in a battery jar filled with water about 20° C. Leave the free side tube of this last U-tube open to the air.

b. Heat the petroleum very gently at first, and then more strongly. The material which has the lowest boiling point will go the farthest before it condenses. Continue to heat until the petroleum solidifies, and then disconnect the hard glass tube from the first U-tube.

c. Break the hard glass tube, and examine contents. What is it? Describe the various products which you have obtained. Place them in evaporating dishes, or saucers, and try to burn them. Compare them with lubricating oil, coal tar, gasoline, and kerosene.

139. How MOUNTAINS ARE MADE

Mountains have been formed in two general ways, *folding* and *faulting*. Both these methods, however, are due to one cause, the cooling of the earth. We may consider the earth, like any other hot body, to have cooled on the outside first. The cooling of the material inside continued, and at the same time the contraction which accompanies cooling took place. Thus the outside crust became loose and was not in close

contact with the inside sphere. Under these conditions, waves and billows in the surface of the crust would be formed, producing vast folds. These folds formed mountains, which have been worn by erosion until we can see many of the layers bent and twisted. If, however, there were weak spots in the surface of the earth's crust, one part would slip, leaving the rest elevated. The part remaining in its original position would form a mountain. We called this process *faulting*.

References: —

1. 1205 : 210-211. **Folded Mountains.**
2. 1304 : 99-101. **Cause and Types of Mountains.**
- a. 1203 : 45-49. **How Mountains May Be Formed.**
- b. 1206 : 322-328. **Cause of Mountain Growth.**
- c. 1209 : 256-257. **Origin of Mountain Ranges.**
- d. 1210 : 238-246. **Mountains — their Origin and Structure.**
- e. 1301 : 337-343. **Development and Cause of Mountains.**
- f. 1302 : 191-193. **Formation of Mountains.**
- g. 1303 : 178-180. **Formation of Block Mountains.**
- h. 1305 : 248-253. **Formation and Erosion of Mountains.**
- i. 1306 : 362-364. **The Origin of Mountains.**
- j. 1307 : 71-75. **Folded and Block Mountains.**
- k. 1308 : 50-51. **Origin and Erosion of Mountains.**
- l. 1309 : 86-89. **Formation of Mountains.**
- m. 1310 : 284-286. **Types of Crystal Deformation.**

140. THE SOURCE OF FOOD — THE SOIL

Vegetable food must always be the real source of our energy and sustenance. While meat forms part of our diet, as well as vegetables and fruits, yet we must realize that our meat-producing stock lives upon grains and other plant growths.

Thus we must in the end depend upon those who will till the soil. Moreover, if these agriculturists would only realize the nobility of their profession, would study and put into

practice what they learned, they would be carrying out a system of work which is unequaled in its opportunities for original research, and in which experiments show results very quickly in every line of action. All growth is dependent upon the soil; therefore we shall begin with this part and carry the study through a consideration of plants to animal life.

Soil is made by two general agents: those which have no life, which we call the inorganic, under which come water, air, and winds; the others organic, including microorganisms, and larger plants and animals. We are not likely to appreciate fully the amount of work that is being done to improve our soil, but rather to think only of the damage done to a few of our plants by the same agents. See Section 131, Disintegration due to Plant and Animal Life.

References: —

1. 1205 : 19-22. The Soil and its Production.
2. 1304 : 338. Importance of Soil.
3. 1503 : 91. Composition of Soil.
4. 1601 : 31-36. Relation of the Soil to Organic Evolution.
5. 1605 : 75-78. What Soil Is.
 - a. 1202 : 345-349. The Chemical Nature of Soil.
 - b. 1603 : 1-6. The Origin of the Soil.
 - c. 1604 : 29-40. Soil Makers.
 - d. 1606 : 17-22. How Soils are Made.
 - e. 1607 : 49-52. Nature and Origin of Soil.
 - f. 1608 : 16-18. The Sunlight.
 - g. 1611 : 18-33. The Soil: How Made and from What.
 - h. 1612 : 23-32. What we Find in Soils.

141. THE FARM A WORKSHOP

The farm should be considered as a factory in which the farm products are manufactured. It is just as impossible in farming to get something for nothing as it is in any other

business. It may be that the land is well stocked with all the material necessary to produce a healthy growth of all kinds of crops, and so the farmer may go on, year after year, without taking any care of his land. Sooner or later, however, the time will come when all the valuable plant food has been removed from the land, and it becomes worthless. This is the cause of many an abandoned farm. If, however, the farmer returns to the soil those elements and combinations of elements which have been removed by the particular crop which he has just harvested, the land will remain in a proper condition. Nowadays the farmer can have access to books in which are given tables that show just what kind of plant food is necessary for each kind of crop, and just how much of each material is taken away for every ton of harvested crop. He may then know just how much material he must return to the soil. Thus some crops, *e.g.* wheat, require a large amount of phosphorus, and that plant food must be returned to the soil, or it will be impossible to raise another crop of wheat, unless, as has been mentioned, there is a large store of phosphorus in the land. It must be remembered, however, that it is poor economy to exhaust the natural fertilizer of the soil, for the commercial fertilizer; that is, any fertilizer made by man is not as readily assimilated by the plants as the natural plant food. There are three general kinds of plant food: nitrogen, phosphoric acid, and potash.

References: —

1. 1601 : 3. The Business of Farming.
2. 1605 : 380-383. Farm Records and Accounts.
 - a. 1604 : 4. The Meaning of the Word *Farm*.
 - b. 1606 : 11. Agriculture and Business.
 - c. 1713 : 150. Field Trials.

142. RESOURCES OF THE SOIL

By resources is meant not only the plant food as such, but the total amount of surface material which can be changed into plant food by nature, or by man. It is a great advantage that most of the plant food is still locked up by nature, otherwise man, in his rapacity, would have deprived the soil of its usefulness hundreds of years ago.

Nature maintains the fertility of the soil by returning to the ground the decayed plant material. Man has done what he can to deplete the resources of the soil by removing from it all the plant growth. Yet, as the farmer becomes more educated in his own work, he is gradually copying nature and considers the land as a factory, rather than as a place from which he can get something for nothing.

The useful constituents of the soil are carbon, sulphur, oxygen, phosphorus, calcium, soluble silicates, and a few other chemicals, which do not enter into the plant growth to any great extent. We are often misled by a chemical analysis of the soil, for it shows the total amount of material present in the soil, without stating whether that material is available for plant food. Thus, chemical analyses may show a soil to be rich in everything that goes to produce plants, and yet it may be incapable of sustaining plant life. What we are interested in chiefly is the amount of available plant food — that is, the food which the plants can obtain readily from the ground. Fertilization of the land is the addition of the missing constituents of plant food. Besides supplying definite wants, foreign fertilizing material has the further effect of in some way stimulating the plants.

There is another resource of the soil which is coming more and more to be reckoned as the chief cause of plant growth.

This is the incalculable amount of bacteria present. These bacteria serve many purposes of disintegration and decay, and are also able to abstract the nitrogen of the air, and change it into nitrates, which are then readily absorbed by the plants. A little later we will take up a more complete study of bacteria in relation to plant growth.

References : —

1. 1601 : 36-37. The Soil a Laboratory.
2. 1601 : 76-88. Chemical Constituents of the Soil.
3. 1601 : 101-106. Store of Plant Food.
4. 1605 : 109-113. Plant Food in Soils.
5. Farmers' Bulletin, No. 342 : 5-10. Conservation of Soil Resources.
 - a. 1602 : 39. Make-up of Rich Soil.
 - b. 1606 : 18-22. The Organic Elements and Agents.
 - c. 1606 : 25-28. Resources of the Soil.
 - d. 1610 : 35-36. Natural Strength of Soils.
 - e. 1611 : 141-142. Soil Bacteria.
 - f. 1612 : 62-70. How Plant Food is Preserved.
 - g. 1612 : 71-78. Getting Acquainted with Plant Food, Chemical Analysis.
 - h. 1713 : 149-150. The New Theory of Liebig.

143. KINDS OF SOILS

Soils are classified according to the labor which is required to work them properly and in respect to their water-holding capacity. Thus graded, soils are called heavy, compact, sandy, light, porous, cold, and warm. There is another classification which is due to the composition of the soils; namely, gravelly, loamy, swamp, peat, or humus soils.

References : —

1. 1205 : 19-22. The Soil.
2. 1503 : 91-92. Kind of Soil Favorable to Evaporation.

3. 1601 : 64-68. Humus Soils.
4. 1601 : 99-101. Kinds of Soils.
5. 1605 : 78-79. How Soils are Named.
6. Farmers' Bulletin No. 408 : 38-40. Classification of Soils.
 - a. 1202 : 345-359. Chemical Nature of Soils.
 - b. 1202 : 371-372. Kinds and Classification of Soils.
 - c. 1203 : 238-240. Varying Characteristics of Soils.
 - d. 1206 : 120-121. The Soils.
 - e. 1312 : 402-403. Soil and its Varieties.
 - f. 1608 : 25-28. Other Classes of Soils.
 - g. 1608 : 33-37. Types of Soils.
 - h. 1610 : 23-28. Classification of Soils.

144. TRANSPORTATION OF SOILS

If we examine the surface soil and the lower layers of soil, we are liable to find that they are entirely different. This indicates that the soils have been brought from some other place and deposited. Soils do not always stay where they are formed.

The factors which enter into transportation of soils are wind, water, and earthworms, together with other lower organisms. Rivers carry an immense amount of soil-making material, and often deposit it, thus changing the river's course. This alluvial soil is one of the richest which we have. Rain wears away hills and mountains and supplies the rivers with their burden of soil. In colder climates, as we have learned, the frosts break up the soil and loosen it, preparing it to be washed away by the rain. In larger masses of ice, namely, glaciers, enormous transportation of rock and soil takes place. We can see this where there have been glaciers in prehistoric times, and can realize, on account of the actual mountains of material which they have left, that their load must have been tremendous. Winds also move the soil of

the lighter varieties, forming sand dunes which often overwhelm the fertile soils underneath, although, in time the sand itself will make good soil.

The transportation of soil by organisms has not, until lately, been fully appreciated. The amount of earth which is brought up by the earthworms is almost incredible, but most of us are familiar with the disturbance of the ground by moles and gophers. There are still smaller organisms, which are invisible, that cause the material of which the soil is composed to be more readily disintegrated, and carried away by the other forces. Plants also move soils to a certain extent, or so loosen them that they can be more readily moved by wind or water.

References: —

1. 1205 : 145-147. Transportation by the Wind.
2. 1304 : 43. Residual and Transported Soils.
3. 1601 : 50-54. The Work of Rain.
4. 1601 : 54-61. Glacial Soils.
5. 1601 : 61-64. Earthworms as Soil Workers.
 - a. 1302 : 113-114. Transportation by Glaciers.
 - b. 1303 : 136-138. The Wasting of the Lands.
 - c. 1305 : 216-219. Transportation of Rock and Soil.
 - d. 1309 : 146-150. Transportation and Deposition.
 - e. 1311 : 87. Transported Waste.
 - f. 1604 : 41-49. Soil Carriers.
 - g. 1604 : 63-68. Field Laborers.
 - h. 1606 : 22-25. Transportation of Soils.
 - i. 1612 : 17-22. The Soils that Living Things have Made.

145. TEXTURE OF THE SOIL

The size of the particles comprising the soil causes its various textures. Thus, if the particles are large, the soil is said to be coarse, and, if they are small, we call the soil fine.

We are not so much concerned with the size of the particles as we are with the effects which the various sizes produce. By measurement it has been learned that the smaller a particle becomes, the larger the surface is, compared with its volume. For that reason, a given amount of soil, if fine, has a much greater surface than if it were coarse. Now water clings to the surface, and in a fine soil we will find a larger amount of water than in a coarse soil. Yet, on the other hand, if the soil becomes too fine, it is liable to pack and take on the effect of a rock rather than a mass of soil.

References: —

1. 1205 : 19-20. The Soil Layers.
2. 1601 : 70-76. Soil-texture, and its Influence.
3. 1605 : 76-78. The Size of Soil Particles.
4. Farmers' Bulletin No. 187 : 6-8. Mechanical Make-up of Soil.
5. Farmers' Bulletin No. 266 : 27-28. Organic Matter Affecting Texture.
6. Farmers' Bulletin No. 408 : 39-40. Porosity — the Water Capacity of Soils.
 - a. 1202 : 367-370. Physical Condition of the Soils.
 - b. 1404 : 113-116. Texture of the Soil and its Effects.
 - c. 1602 : 33-35. The Ideal Soil.
 - d. 1604 : 125-127. Texture of the Soil.
 - e. 1606 : 38-41. What is Meant by Texture, and its Importance.
 - f. 1607 : 231-232. Tillage to Modify Soil Texture.
 - g. 1611 : 62-64. Soil Crumbs.
 - h. 1612 : 34-43. Concerning the Texture of Soil.

Experiment 72. — Water Capacity of Soils.

Apparatus: Five or more argand lamp chimneys in a rack to hold them vertical over the same number of table tumblers or beakers, cheesecloth in squares $3'' \times 3''$, string.

Materials: Sufficient sand, gravel loam, peat, clay, broken stone, and samples of local soils, to fill the chimneys.

a. Cover the small end of each chimney with cheesecloth, and fill with different materials; place tumblers under each chimney, and pour the same amount of water into each. Time the flow of water through each.

146. IMPORTANCE OF MOISTURE

We are now concerned with the importance of moisture to the farmer. Water, and its uses, are treated under other heads. Plants can only absorb their food when it is dissolved in water, and the amount of water is huge when compared with the quantity of food which is taken up at the same time. Then also, if the soil is not moist, it becomes hard, and the plants cannot force their roots through it, in order to obtain their food. In addition to this, a very large percentage of all plants is actually water. Thus there may be very rich soils which could support enormous growths of vegetation, if it were not for the fact that the rainfall is very slight. Many of our deserts, where they have been watered artificially, have become the best producing places on earth.

References : —

1. 1304 : 337-338.	Importance of Moisture.
2. 1407 : 28.	Absorption of Water by Roots.
3. 1503 : 143-146.	Water Supply for Plants.
4. 1601 : 155-156.	Amount of Water Used by Crops.
5. 1605 : 84-85.	Importance of Soil Water.
6. 1702 : 155-157.	Water Content of Plants.
a. 1602 : 21-23.	Plants and Water.
b. 1604 : 124-127.	The Necessity for Moisture.
c. 1606 : 47-48.	Why Moisture is Important.
d. 1608 : 43-46.	Kinds and Uses of Soil Moisture.

- e. 1609: 38-40. Importance of Moisture.
- f. 1611: 34-35. What Water Does in Soils.
- g. 1611: 55-59. Plant Food in Soil Water.

147. HOW WATER IS HELD IN THE SOIL

In Section 145, Texture of the Soil, we noted that the smaller the particles were, the more surface they had, and the larger amount of water they could then hold. Water is held in the soil by actual porosity, just as water is held in a sponge; it is also held by capillarity, in the same way that oil travels up a lamp-wick. See Section 118, Capillarity. Finally, it is held in a chemical method, forming almost a compound with the soil. This is called *hygroscopic water*. See Section 122, Hygroscopic Salts. The wise farmer makes use of these characteristics in order that his crops may receive sufficient water. This will be considered under Tilling the Soil, Sections 148-149.

The water which merely fills the larger spaces in the soil rapidly passes away, soaking into the earth, and does not enter much into the food supply of plants. The capillarity causes the lower water to creep up and keep the upper layers constantly moist. The hygroscopic water is so closely bound to the soil that the soil may feel perfectly dry, although containing considerable moisture. Hygroscopic water, then, is of no value whatsoever to the farmer.

References: —

- 1. 1503: 91-92. How Water is Held in the Soil.
- 2. 1601: 157-162. Capacity of Soils to Hold Water.
- 3. 1605: 79-81. Relation of Size of Particles to Water.
 - a. 1602: 17-20. The Soil and Soil Water.
 - b. 1603: 10-14. The Moisture of the Soil and How it Moves.
 - c. 1604: 128-129. The Movements of Water in the Soil.

- d.* 1606: 48-50. How Water is Held in the Soil.
- e.* 1607: 129-133. How Water is Held in the Soil—Soil Capacity.
- f.* 1608: 43-45. Kinds of Moisture.
- g.* 1611: 41-45. How Water is Held in the Soil.
- h.* 1612: 40-43. Three Forms in which Water Exists in the Soil. Water-holding Capacity.

148. TO INCREASE THE MOISTURE-HOLDING CAPACITY— TILLING

The two aims of the farmer are to obtain as large an amount of water as possible, and to conserve this water. If the soil is left in its natural condition, a large percentage of the water will run off, little being absorbed. To increase the capacity of the soil for holding moisture, it should be loosened, and left rough to prevent this surface water from running off, and the amount of *humus*, which will be described later (Section 153), should be increased. The idea is to render the soil as porous as possible, so that the water may be absorbed rapidly. Underdrainage takes a large amount of water away from the soil, yet it leaves the soil porous, thereby increasing its capillarity, and the water level, or, as it is called, the water table, is maintained more nearly at the proper depth, than without underdrainage. Under these conditions the soil causes the water to rise from the water table, and there is more water available for the plants. Any tilling, or cultivating of the land, which breaks up the soil into finer particles, increases its moisture-holding capacity.

By tilling of the soil is meant any artificial changing of the surface of the ground, to prepare it for planting, or to aid in the growth of the plants. The removal of weeds also comes under this heading, since they deprive the soil of plant food, which is thus lost. It is only in modern times that the ad-

vantages accruing from the tilling of the soil have been fully appreciated.

Tillage may be performed by the use of a plow, cultivator, harrow, spade, hoe, rake, or any drag which tends to break up clods and pulverize the surface of the soil. Ordinarily, the terms *tilling* and *cultivating* are synonymous. The wise farmer cultivates the soil after each rain, as soon as the surface dries sufficiently, in order to preserve the moisture.

References: —

1. 1601 : 157-162. Capacity of Soils to Hold Moisture.
2. 1601 : 192-194. Cultivation and Harrowing.
3. 1605 : 87-88. Dry-land Farming.
4. 1605 : 165-166. Methods in Tilling.
5. Farmers' Bulletin No. 245 : 6-7. Soil Moisture and Humus.
6. Farmers' Bulletin No. 266. Cultivation to Retain Moisture in the Soil.
 - a. 1603 : 6-9. Tillage of the Soil — Origin of the Term.
 - b. 1604 : 60-72. Field Laborers.
 - c. 1606 : 50-56. How the Moisture-holding Capacity may be Increased.
 - d. 1606 : 64-72. Tillage of the Soil.
 - e. 1608 : 56-57. Benefits, Advantages, and Methods of Tillage.
 - f. 1610 : 47-49. Tillage, Fall Plowing, and Subsoil Plowing.
 - g. 1611 : 60-69. Tillage, and How it is Performed.
 - h. 1612 : 96-98. The Increase of the Water-holding Content.

149. CONSERVATION OF MOISTURE — TILLING

Water is lost from the soil by evaporation from the surface of the ground, and from the surface of plants growing in the soil. While this evaporation from the crops cannot be prevented, and it is not to be desired, yet by the removal of weeds we can prevent a large unnecessary evaporation. As far as

possible, all the water of the soil should be forced to pass up through the cultivated plants, carrying with it plant food. Any water which passes out of the soil through other means is a loss. The prevention of unnecessary loss of water is called *conservation*.

The capillarity of the soil must be broken up, which can be accomplished by loosening the surface, and leaving what is called a *dry mulch*. There are some practices which seem to produce the desired result, although they cause loss. If the land is rolled, it becomes wetter, yet this dampness is taken from the lower soil, and when the surface water has evaporated, as it will shortly, the land will be much drier than it would have been if left unrolled. There is considerable loss due to the winds, as air in motion is capable of absorbing much more water than still air. Therefore windbreaks, which will lessen the velocity of the wind, will tend to prevent evaporation from the surface of the land.

The first tillage, in preparing the soil for planting, loosens it, and exposes the under layers to the action of the air, and also brings more plant food to the surface. In order that plants may grow well, the surface of the soil must be rather finely broken and loosened, so that the tender roots may easily get a start. After planting, the soil is cultivated chiefly to conserve the water, or to cause the lower water to rise, and come within reach of the plant roots. We learned that moisture moves through soil by means of capillarity. Loosening the soil beneath the surface increases the capillarity, and causes the water to rise from the lower levels. On the other hand, tilling the surface of the ground causes the pores to be closed and evaporation is prevented. This surface layer of finely pulverized dry material is called a *soil mulch*, and the process of its formation is called *mulching*. A rain will

destroy the soil mulch, leaving pores through which evaporation can take place readily. For that reason, cultivation after a rain is necessary, if the moisture is to be conserved.

References:—

1. 1601 : 184-202. The Conservation of Soil Moisture.
2. 1605 : 84-85. Conservation of Moisture.
3. Farmers' Bulletin 245 : 8-9. Effects of Tillage.
4. Farmers' Bulletin 266. Management of Soils to Conserve Moisture.
5. Reprint from Yearbook Department of Agriculture for 1908. Soil Mulches for Checking Evaporation.
 - a. 1602 : 55-56. Saving Soil Moisture.
 - b. 1603 : 10-14. The Moisture of the Soil and How it is Retained.
 - c. 1606 : 56-57. Conservation of Moisture.
 - d. 1610 : 50-51. Tillage Conserves Moisture.
 - e. 1611 : 46. How to Prevent Evaporation by Mulching.
 - f. 1612 : 88-98. The Rôle that Tillage Plays.
 - g. 1612 : 164-175. Soil Water: How it is Lost; How it may be Held.

Experiment 73. — The Effect of Mulches.

Apparatus: Balance, set of weights, five glass chimneys which are very large at the bottom, stoppers for the small end of the chimneys.

Materials: Loam, sand, sawdust, leaf mold.

a. Stopper the small end of the chimneys, fill them nearly full of loam, and wet the loam with all the water it can hold without water running out of the chimneys when they are inverted. Put a layer of very dry loam half an inch thick on the top of the wet loam in one chimney; a similar layer of sand in another chimney; sawdust in the third chimney; leaf mold in a fourth. Put nothing on top of the wet loam in the fifth chimney.

Weigh all the chimneys, with their contents, taking care to number them. Weigh every twenty-four hours, and make a table of your results. State your conclusions.

150. IRRIGATION AND UNDERDRAINAGE

The artificial watering of land is called *irrigation*. Irrigation is of the utmost importance, since about two-fifths of the area of the United States is too dry for farming. Up to the present time, a little over ten million acres are irrigated, which is a mere nothing compared with the dry area. Proper irrigation, that is, where there are several thousands of acres to be irrigated, must be a national enterprise, since it is impossible for communities, or even groups of men, to combine in order that they may put into operation any large irrigation system. Irrigation should be used where the soil needs more water, whether in a dry or humid climate. Although the cost of irrigation is considerable, yet the results pay, for it will give a large pecuniary gain. In this connection it might be well to understand that the actual outlay of money for improvements must not be thought of as expense, if the returns justify the expenditure. The same is true in the fertilization of the soil. If the addition of several hundred dollars' worth of fertilizer produces enough extra crop to pay for the fertilizer and give a fair profit, the cost of the fertilizer should not be considered at all. For the practical consideration of irrigation in field and garden, Farmers' Bulletin No. 138, written by Professor E. J. Wickson, leaves little unsaid.

Too much water is nearly as bad for plants as too little water; they will not grow if the roots remain in water, since the necessary air is thereby excluded from them. *Under-*

drainage not only improves land when it is too wet, but in the dry time the crops grow better; for they have run their roots down farther to seek the dampness, which has been lowered by the drainage. Thus the plants have more soil from which to draw. Also, since the land is left porous, the water-holding capacity is increased.

Drainage may take place on the surface, as well as from underneath. If the land is very cheap, it may not be worth while to go to the expense of putting in a system of underdrainage. If, however, the land is valuable, underdrainage should by all means be made use of, not only to save the surface area, but also to make the tilling and planting more convenient.

References: —

1. 1601: 253-264. Farm Drainage.
2. 1601: 269-275. Irrigation in Humid Climates; Cost and Results.
3. 1605: 88-90. Irrigation.
4. 1605: 91-94. Drainage.
5. Farmers' Bulletin No. 138. Irrigation in Field and Garden.
6. Farmers' Bulletin No. 158. How to Build Small Irrigation Ditches.
7. Farmers' Bulletin No. 187. Drainage of Farm Lands.
8. Farmers' Bulletin No. 263. Practical Information for Beginners in Irrigation.
9. Farmers' Bulletin No. 371. Drainage of Irrigated Lands.
 - a. 1308: 167-171. The Distribution of Water.
 - b. 1309: 319-321. History of Irrigation.
 - c. 1310: 134-137. The Effects of Irrigation.
 - d. 1404: 130-133. The Amount of Water for the Best Effects.
- e. 1602: 34-35. Drainage Necessary.
- f. 1603: 15-17. Draining the Soil.
- g. 1606: 53-54. Beneficial Effects of Underdrainage.

- h. 1608: 50-51. Drainage and Ventilation.
- i. 1610: 42-43. Drainage and Irrigation.
- j. 1611: 49-53. Irrigation.
- k. 1612: 152-153. Draining the Land.

151. SOIL AIR

Air is necessary for plant growth, as well as for animals. The plants need it themselves, and the soil bacteria require it, and must use it in the formation of the nitrates. Then, also, oxygen is needed to carry on some chemical changes of decomposition, as well as to prevent the loss of the nitrate-forming material. If the soil is too wet, the air is excluded, and for that reason, drainage is necessary. Drainage, either natural or artificial, is necessary for plant growth.

The soil is ventilated by natural means, due to the changes of temperature, causing expansion or contraction of the air in the soil; by changes of barometric pressure; and by the changing of the level of the water table. Man can accomplish much in the direction of soil ventilation by underdrainage.

References: —

- 1. 1601: 239-244. Needs of Soil Ventilation.
- 2. 1601: 244-248. Natural Process of Soil Ventilation.
- 3. 1601: 248-251. Ways of Influencing Soil Ventilation.
- 4. 1605: 94-95. Importance of Soil Air.
- 5. Farmers' Bulletin No. 245: 7. Soil Air.
- 6. Farmers' Bulletin No. 408: 37-38. Air Necessary for Plant Growth.
- 7. Bureau of Soils, Bulletin No. 73: 25-30. Oxidation in Soil.
 - a. 1207: 330-331. The Atmospheric Circulation of the Soil.
 - b. 1602: 34. The Air and Water in Soil.
 - c. 1607: 125-127. Movement of Air Through Soil.
 - d. 1608: 52-54. Soil Ventilation and its Effects.
 - e. 1611: 6. Soil Air.
 - f. 1612: 36. Air Circulation in Soils.

EXPERIMENT FOR THE TEACHER

See Farmers' Bulletin No. 408:37. Air Necessary for Plants.

If the botanical side is to be emphasized in the course, this bulletin may be used to great advantage as a source of information concerning experiments.

Experiment 74. — Air Necessary for Roots.*

Apparatus: Two tumblers, or beakers, 125 c.c.

Materials: Geranium cuttings, sweet oil.

a. Boil some water, to drive out the air, cool it, and then fill the two glasses three fourths full. Put a cutting of geranium in each, but cover the surface of the water in one glass with a thin layer of sweet oil. Observe the growth of roots.

Soil which is too wet produces the same result.

152. PLANT FOOD—I

The principal plant foods are nitrogen, phosphoric acid, potash, and substances called *amendments*, which tend to set free plant food already in the soil. Fertilizers contain different compounds of the above substances.

When we add a fertilizer to the soil, we say that we are improving the land. In reality, we are not interested in whether the land is good or bad, but we are careful to see that the coming plants will have food enough; just as we do not throw food out into the chicken yard to improve the chicken yard, but to feed the chickens. There may be a large amount of plant food already in the ground, but unless it is in a condition in which it can be absorbed by the plants, it might as

* From Farmers' Bulletin No. 408.

well not be there. The plowing of land tends to bring up, and expose to the action of the air lower layers of plant food, and for this reason it is advantageous, where the soil is fairly thick, to plow quite deeply.

Plants are unable to absorb the nitrogen of the air directly, but must obtain it through a solution of some compound, which is taken in through the roots. This is true of all plant food. Compare Leaves, Section 165. There are certain bacteria that grow on the roots of alfalfa, beans, peas, lentils, cowpeas, and other leguminous plants, which have the power of absorbing the nitrogen of the air and changing it into some nitrate, which is then readily absorbed by the plant. If these bacteria are not present, there must be some nitrate added to the soil, and this is very often sodium nitrate. Barnyard manure is a rich source of nitrogen.

Phosphoric acid itself is not added to the soil, but some soluble phosphate is used. The plant takes what it needs. The chief source of phosphoric acid is calcium phosphate, which has been rendered soluble by changing it into a lower phosphate by sulphuric acid, and it is the phosphorus part which is made use of by the plant. Other sources are barnyard manure, bone and refuse from meat-packing houses.

Potash is necessary for the development of plants, and plays a large part in the formation of seeds. The potassium does not seem to supply material for food directly, but aids in the changes and assimilation of the starches and sugars. Some plants need much more than others, but potash is found throughout the whole of every plant. Thus the ashes of wood is a source of potash.

The organic acids form salts with the potash acquired from the soil, and the amount formed shows the energy of the plant. Since chlorine seems to be needed in the changing of the hy-

drocarbons into a soluble form, potassium chloride is best for fertilizing purposes, and this is especially true during the period of fruition.

References: —

1. 1601 : 80-81. Potassium in the Soil.
2. 1601 : 101-106. The Store of Plant Food.
3. 1601 : 107-134. Nitrogen of the Soil.
4. 1605 : 25. Potash.
5. 1605 : 116-120. Nitrogen and its Fixation.
6. 1605 : 123-124. Phosphorus.
7. 1605 : 126. Lime as an Amendment.
8. Farmers' Bulletin No. 77 : 7-9. Chemical and Physical Effects of Lime.
 - a. 1602 : 53. Sources of Plant Food.
 - b. 1603 : 33-3 . Root Tuberles.
 - c. 1604 : 139-156. Food from the Soil.
 - d. 1606 : 85-98. Enriching the Soil.
 - e. 1608 : 128-135. Applied Plant Food.
 - f. 1609 : 211-214. Potassium in Plants.
 - g. 1610 : 10-15. Sources of Plant-food Elements; the Air and the Soil.
 - h. 1611 : 55-59. Plant Food in Soil Water.
 - i. 1612 : 52 61. The Elements that Plants Use.
 - j. 1612 : 64-66. Available and Nonavailable Plant Food.

153. HUMUS

Humus is composed of decayed vegetable and animal matter which, in the natural humus, has accumulated through untold thousands of years. It is what gives the soil the dark color, and is absolutely necessary for plant life. As has been noted, it increases the water-holding capacity, loosens heavy soils, and serves as food for bacteria, which play such an important part in agriculture.

Living upon the humus to a great extent, the bacteria cause decay, and produce nitric acid from the nitrogen contained in

the humus. This nitric acid acts upon some of the insoluble compounds of the soil, changing them into nitrates, which are readily absorbed by the plants. In the decaying humus carbon dioxide is liberated, which dissolves more of the minerals, forming plant food. The humus also aids the growth of the nitrogen-fixing bacteria. The study of the bacteriological influences upon agriculture will be considered under Bacteria. See Sections 155 and 173.

A further study of humus will be taken up in the consideration of green manures. See Section 155.

References: —

1. 1205: 20-21. How Humus and Subsoil are Mingled.
2. 1601: 64-68. Humus Soils.
3. 1601: 95-96. Chemical Constitution of Humus.
4. 1605: 95-96. The Uses of Humus.
5. Farmers' Bulletin No. 78: 5-7. Importance of Humus.
6. Farmers' Bulletin No. 192: 30. The Cumulative Effect of Barnyard Manure in Producing Humus.
7. Farmers' Bulletin No. 245: 11. Improving the Soil by Increasing the Humus.
 - a. 1404: 107-108. Humus.
 - b. 1602: 42-43. Humus in the Soils.
 - c. 1603: 21. Adding Humus to the Soil.
 - d. 1606: 52. Effects of Humus on Soil Water.
 - e. 1607: 76-77. Humus.
 - f. 1608: 31-32. Humus.
 - g. 1610: 25. Humus.
 - h. 1611: 24-25. Humus.
 - i. 1612: 286-290. Getting Humus into the Soil.
 - j. 1713: 148-149. The Humus Theory.

154. ENRICHING THE SOIL

If the soil is lacking in any of the plant food which has been mentioned, that material should be added in order to obtain

the best results. The richness of the soil may be measured by the amount of that plant food which is present in the smallest degree; that is, the soil may have plenty of potash and phosphoric acid, but if it is weak in nitrogen, its value is no greater than is its nitrogen content. Thus the addition of nitrogen, in this particular case, would allow the other plant food to act proportionally, and the result would be greater than that due to the mere addition of the nitrogen alone. Any addition of plant food to the soil is called enriching the soil.

The materials used for enriching the soil are treated under the various paragraphs concerning plant food. Yet we must remember that humus is absolutely necessary to make plants grow well. The best methods for increasing the humus content is by the use of green manures and barnyard manure.

References: —

1. 1601 : 285-288. Texture of Soils Influenced by Fertilizers.
2. 1605 : 114-128. Materials Used as Fertilizers.
3. 1901 : 117-118. Bacteria in the Soil.
4. Bureau of Soils, Bulletin No. 73 : 7-8. Liebig's *vs.* the Modern Idea of Fertilization.
 - a. 1603 : 18-21. Improving the Soil.
 - b. 1606 : 77. What Farm Resources Are.
 - c. 1606 : 83-84. Other Dressings.
 - d. 1610 : 41-44. The Improvement of Soils.
 - e. 1611 : 147-148. How to Use Fertilizers.
 - f. 1902 : 57-65. Nitrification and Bacteria.
 - g. 1902 : 111-117. Bacteria and Soil Minerals.

155. GREEN MANURES

Crops which are grown for the purpose of being plowed under, are called *green manures*. Cowpeas, crimson clover, and various legumes are used for this purpose, and the result is twofold: the supply of humus is increased, and the nitro-

gen is obtained, both from the bacteria of decay acting on the green manures, and from the nitrogen-fixing bacteria which have grown on the roots of these plants. Green manures are the only salvation for the land when it has run out completely.

Green manures need not interfere with the regular crops, unless the land is very poor, for they may be planted in the fall or early spring, as catch crops, being plowed under before planting the regular crop. It means a little more labor to the farmer, but in no other way could he get so much return for the time he spends in thus increasing the available plant food.

References:—

1. 1601: 190-192. Early Seeding and Catch Crops.
2. 1605: 147. Green Manures.
3. Farmers' Bulletin No. 245: 12-15. Green Manures.
4. Farmers' Bulletin No. 278. Leguminous Crops for Green Manuring.
5. Farmers' Bulletin No. 374: 5-7. Inoculation and Lime for Alfalfa.
6. Bureau of Plant Industry, Circular No. 71. Legume Inoculation and the Litmus Reaction of Soils.
 - a. 1602: 45-48. How Clover Helps the Farmer.
 - b. 1603: 33-35. Root Tubercles.
 - c. 1606: 78-81. The Kinds and Management of Green Manure.
 - d. 1607: 201-202. Danger from Green Manuring.
 - e. 1610: 44-47. Green Manuring and Suitable Plants.
 - f. 1611: 141-143. Green Manure.
 - g. 1612: 289. The Help from Green Manure.
 - h. 1902: 95-110. Legumes and Bacteria.
 - i. 1903: 237-263. Green Manures.

156. BARNYARD MANURE

This source of plant food is by far the most important that the farmer can apply to his land. It has been long known,

but its value has not been fully realized. Even at the present time, many farmers do not appreciate the losses they sustain when they do not take the proper care of their barnyard manure. The value of this dressing is sometimes reckoned in the amount of nitrogen, potash, and phosphoric acid it contains. Nevertheless, this is not the whole value, for it can produce large quantities of humus, which, decaying, sets free nitrogen, and also increases the necessary bacterial life in the soil.

On account of thoughtlessness or ignorance, fully one half the value of the manure is lost by the flowing away of the liquid part. There is another great loss by rain, or by the water flowing from the roof, where the manure has been left piled against the building. The best way to handle manure is to spread it as fast as it is produced. If this is impossible or undesirable, the manure should be kept in a building with a cement floor, tramped and kept moist by some animals, and then spread all at once. The layer of manure should be quite thin, especially where it is fresh manure, as larger amounts may destroy the plant life on account of the rapid fermentation. In this connection it is well to note that properly fermented manure is better for plants; the additional value is not great enough, however, to pay for the very large loss which takes place during the fermentation, and it is more desirable to use smaller quantities of the fresh manure.

References: —

1. 1601: 288-291. Barnyard Manure and Soil Moisture.
2. 1605: 135-147. Barnyard Manure.
3. Farmers' Bulletin No. 162: 5-6. Value of Barnyard Manure.
4. Farmers' Bulletin No. 192. Barnyard Manure.
 - a. 1606: 81-83. Stable Manures.
 - b. 1608: 130-131. Barnyard Manure.
 - c. 1610: 54-60. Barnyard Manure.

- d.* 1611: 139-141. Farmyard Manure.
- e.* 1611: 216-226. Handling Manure on the Farm.
- f.* 1612: 206-215. Barnyard Manure.
- g.* 1902: 69-76. Barnyard Manure and Bacteria.
- h.* 1903: 306-317. Losses from Barnyard Manure.

157. RENOVATION OF WORN-OUT SOILS

Any soil which has ever produced a crop may, with care and patience, be made to produce again, just as bountifully and perhaps more bountifully. Farmers' Bulletin No. 245 gives an excellent summary of the whole matter, as well as a general review of many topics which have been studied in this connection.

References:—

- 1. Farmers' Bulletin No. 245. Renovation of Worn-out Soils.
- 2. Farmers' Bulletin No. 406. Soil Conservation.
- 3. Reprint from Yearbook Department of Agriculture, 1908.
 Plant Food Removed by Rain.
 - a.* 1612: 282-290. What may be Done to Renovate Worn-out Soils.
 - b.* 1606: 20-22. Worn-out Land Lacks Humus.
 - c.* 1902: 119-122. Soil Inoculation and the Control of Soil Bacteria.
 - d.* 1903: 152-154. Maintaining Soil Fertility.

158. THE LIMING OF THE SOIL

Lime corrects the acidity of the soil, and since it liberates plant food, it should be classified as an amendment rather than as a fertilizer. See Section 121, Acids, Bases, and Salts. Soil may be tested by blue litmus paper. If it turns red, lime should be applied. It aids the soil organisms in the fixation of nitrogen, and is necessary to obtain the best results from the use of barnyard manures. Some crops need more lime

than others, and this gives us a test for the lack of lime. If red clover fails where it once grew, it is a sure indication that lime should be applied to the soil.

The sources of lime are limestone and gypsum, but the limestone, or calcium carbonate, is more desirable. When roasted, this changes into unslaked lime, the material that is used on the soils. There it unites with the water, forming slaked lime, which is rather soluble. In this way the lime can be carried throughout the grains of the soil. A small application of lime lasts for a long time. On the other hand, an excess of lime does no harm.

In Section 163, Plant Roots, it will be learned that the roots of growing plants give off an acid. Lime neutralizes this acid.

References: —

1. 1205: 10. Acids in Soil Water.
2. 1601: 30. Effects of Lime on Soil.
3. 1605: 126-128. Lime, its Functions and Forms.
4. Farmers' Bulletin No. 77. The Liming of Soils.
5. Farmers' Bulletin No. 259: 7-9. Spreading Lime.
6. Farmers' Bulletin No. 374: 5-7. Inoculation and Lime for Alfalfa.
7. Bureau of Plant Industry No. 71. Legume Inoculation and the Litmus Reaction of Soils.
 - a. 1603: 26. Action of Lime in the Soil.
 - b. 1606: 97-98. Lime as an Amendment.
 - c. 1607: 71. Action of Lime.
 - d. 1610: 64-67. Use and Application of Lime.
 - e. 1611: 146-147. Liming the Soil.
 - f. 1612: 99-107. Liming the Land.

Experiment 75. — The Effect of Lime — Acid Soils.

Apparatus: Beaker 150 c.c., battery jar 6"×8", ring stand, burner, asbestos mat.

Materials: Calcium hydrate, hydrochloric acid, 5 per cent, blue and red litmus, samples of soil where clover has been growing.

- a. Take some of the soil in a battery jar, and add just enough water to cover it. Stir for a few minutes, and then test the water with blue litmus paper. If the paper turns red, it indicates an acid soil. Add a little lime water, or some slaked lime, to the mixture of soil and water, stirring as before. Test again with blue litmus paper. If the soil is still acid, continue to add lime until the soil is neutral.
- b. If the water in the soil in (a) does not indicate an acid, it may be because the acid is too dilute. To concentrate the suspected acid, pour the water from the soil into beaker, and boil down to one twentieth of its original volume. Then test with litmus.
- c. Test dilute hydrochloric acid with litmus, and then neutralize the acid with lime, as in Experiment 65.

159. COMMERCIAL FERTILIZERS

The fertilizers which are on the market are usually the so-called complete fertilizers: that is, they contain the phosphorus, potash, and nitrogen in the proportions which have been found best for general crops. Thus they are not, perhaps, adapted to the particular crops which the farmer wishes to raise, nor do they always supply the plant food which is lacking from a particular field. It is impossible, then, for a farmer to buy a commercial fertilizer which can be very well adapted to his special needs.

The losses which accrue from the use of commercial fertilizers are not confined to this inadaptability to the farmer's needs, but also include the transportation expenses, and the

profits to all those who handle the fertilizer before the farmer receives it. Often a ton of fertilizer has no more material in it which can be used for the real plant food than, perhaps, fifteen hundred pounds; the other five hundred pounds may be merely dirt. This does not cheat the farmer, for the fifteen hundred pounds contain all that he is buying, as is shown by the analysis of the fertilizer. The loss is due to the fact that the farmer must pay transportation expenses on five hundred pounds of useless material. In addition to this, the average farmer, instead of buying from a wholesaler, and saving unnecessary profits, buys from some small retailer, who not only makes a profit, but perhaps does not know much about fertilizers.

References: —

1. 1605: 129-131. Complete Fertilizers.
2. Farmers' Bulletin No. 44: 8-11. Need of Commercial Fertilizers.
3. Farmer's Bulletin No. 44: 11-22. Fertilizing Material.
4. Farmers' Bulletin No. 79: 5-7. Fraud in Fertilizers.
5. Farmers' Bulletin No. 329: 5-6. High-grade *vs.* Low-grade Fertilizer.
 - a. 1602: 40. Commercial Fertilizers.
 - b. 1603: 24-26. Commercial Fertilizers.
 - c. 1608: 128-137. Fertilizers.
 - d. 1610: 68-112. Artificial and Concentrated Manure and Fertilizers.
 - e. 1611: 143-147. Commercial and Mineral Fertilizers.
 - f. 1612: 227-237. Buying Plant Food for the Soil.

160. USE OF COMMERCIAL FERTILIZERS

Whenever fertilizers are used, it must be remembered that plants not only require plant food, but they require it under particular conditions. Plants may die, even though supplied

with plenty of available plant food, if the conditions of the soil are not satisfactory. Ofttimes the improvement of the texture of the soil would cause more productivity than the addition of any commercial fertilizer. Then, also, the plant requires water, air, heat, and light; and these conditions must be supplied in sufficient amount, if the best results are to be obtained.

When a farmer is buying fertilizer, he should realize that the cost of the labor of making poor fertilizer is just as great as in preparing good fertilizer, and therefore the best is, after all, the cheapest. There is no kind of fertilizer which improves the soil as well as barnyard manure. Fertilizers as a rule do not increase the organic matter in the soil. The manure increases the amount of humus, supplies food for bacteria, actually places bacteria in the soil, and contains the necessary plant food.

References: —

1. 1605: 129-131. Complete Fertilizers.
2. Farmers' Bulletin No. 44: 28-33. Principles Governing Use of Fertilizers.
3. Farmers' Bulletin No. 259: 5-6. Use of Commercial Fertilizers.
 - a. 1606: 98-100. Commercial Fertilizers.

161. HOME-MIXED FERTILIZERS

The great advantage of mixing fertilizers at home is that the farmer knows what is in the fertilizer, and avoids all danger of fraud. There is another advantage which comes through coöperation, for, if he combines with his neighbors, he may procure the material in very large quantities, obtain carload freight rates, and produce a fertilizer with home labor very much more cheaply than the cheapest and poorest

fertilizer can be obtained in the market. Not only that, but he can adapt the fertilizer to his particular needs, and to the varying needs of the different parts of his farm. He will learn to experiment, and not to be satisfied with some particular kind of fertilizer just because others have said it is good. He buys no waste material, and so reduces the cost of transportation. The farmer becomes a scientific farmer, and puts more thought toward the production of better results.

References: —

1. 1605: 131-132. Home-mixing of Fertilizers.
2. Farmers' Bulletin No. 44: 22-27. Agricultural *vs.* Commercial Value of Fertilizers.
3. Farmers' Bulletin No. 44: 27-28. Home-mixed Fertilizers.
4. Farmers' Bulletin No. 222: 5-9. Home-mixing of Fertilizers.
5. Farmers' Bulletin No 320: 5-9. Fish Fertilizer.

162. FERTILIZERS FOR GARDEN CROPS

The different garden crops respond differently to the same fertilizer, or, to put it another way, different crops require different fertilizers. So many special examples are given in the Farmers' Bulletins that there will be no mention here, and, moreover, the question is not a general one. Plants seem to react to fertilizers as persons do to medicines. Both fertilizers and medicines do not observe scientific laws, in the exactness of their action, but may require experimentation. There is this difference, however: all plants of the same species react alike to a given fertilizer; with persons, each individual is a special case in his reaction to medicines.

References: —

1. Farmers' Bulletin No. 105: 12-13. Fertilizers for Garden Crops.
2. Farmers' Bulletin No. 162: 6-9. Nitrate of Sodium for Garden Crops.

3. Farmers' Bulletin No. 222: 7-9. Formulas for Fertilizers.
4. Farmers' Bulletin No. 255: 11-12. Fertilizers for the Garden.
5. Farmers' Bulletin, No. 278: 14. Crops to Follow Green Manure.

163. PLANT ROOTS

The use of roots is to hold the plant erect and to supply it with plant food, which is dissolved in soil water. The process by which plant food is absorbed, is called osmosis, and the pressure, which is produced in the plant, is called *osmotic pressure*. See Section 119, Osmosis. Roots grow downward on account of gravity, but later they also grow in the direction of moisture. The length of the root system of a single plant may run into miles, but many of these roots die, only to be replaced, in a few days, by thousands of new ones.

Roots excrete a material which is capable of dissolving some of the insoluble plant food in the soil. The excretion may become harmful to the plant, however, and this is one of the arguments in favor of rotation of crops, since each plant produces a different excretion, which does not seem to harm other plants. The effect of this excretion may be neutralized by the addition of lime. See Section 121, Acids, Bases, and Salts.

References: —

1. 1304: 40-41. The Work of Roots.
2. 1407: 19-33. Roots.
3. 1503: 82-97. Roots and their Work.
4. 1605: 64-65. How the Plant Gets its Food.
5. 1702: 242. Osmosis in Roots.
6. 1702: 312-313. Roots and Tubers as Food.
7. Bureau of Soils, Bulletin No. 73: 17-25. Oxidation and Reduction by Roots.
 - a. 1401: 36-61. Roots.

- b. 1402: 64-73. How the Plant Takes in the Soil Water.
- c. 1404: 87-162. The Work of Roots.
- d. 1405: 31-44. Roots.
- e. 1406: 120-125. Function and Structure of Roots.
- f. 1603: 27-40. The Soil and the Water.
- g. 1604: 124-138. Roots.
- h. 1902: 98-101. Root-tubercl Bacteria.

Experiment 76.—Effect of Plant Roots on Soil.

Apparatus: Saucer, cloth.

Materials: Radish seeds, litmus paper (blue), blotting paper, distilled water.

a. Place a piece of blue litmus paper upon the saucer, and on it place several radish seeds. Cover the seeds with another piece of blue litmus paper, and place over the latter a piece of blotting paper. Moisten all of the paper with distilled water, and cover with a dry cloth. Moisten each day, if necessary, and note any change in the litmus paper. What are your conclusions?

164. PLANT STEMS

The purpose of the stem is to hold up the leaves and flowers to the light, and to supply them with the materials for plant food. Some stems also store food, after it has been made by the leaves, while the stems of a few plants aid in the making of the food. The propagation of some plants is produced by their stems. The main stems, since strength is required, tend to become woody, and in trees serve as a source of wood.

Stems are composed of bundles of very fine tubes through which the sap rises, partly on account of capillarity (see Section 118), and partly due to the osmotic pressure of the roots. See Section 119, Osmosis. The sap goes to the roots through pores in the inner bark.

References: —

1. 1407 : 40-69. Stems.
2. 1407 : 71-79. Work of the Stem.
3. 1503 : 98-121. Buds and Stems.
4. Farmers' Bulletin No. 173 : 8, 11-14. Wood and its Structure.
5. Farmers' Bulletin No. 181. Pruning.
 - a. 1401 : 83-103. Structure of the Stem.
 - b. 1402 : 14-18. Stem.
 - c. 1404 : 224-285. The Work of the Stems.
 - d. 1405 : 49-63. Stems.
 - e. 1406 : 142-148. Stem Forms and Uses.
 - f. 1505 : 49-72. The Stem.
 - g. 1606 : 120-122. The Processes of Growth.
 - h. 1609 : 282-283. The Stem.
 - i. 1611 : 86-90. Stems and their Use.

Experiment 77. — The Pressure of Sap.

Apparatus: Tube $\frac{1}{4}$ " diameter, 6' long, rubber tubing $\frac{1}{8}$ " diameter, 4' long, ring stand with clamp.

Materials: Growing plant in flower pot.

a. Cut off the plant a few inches from the ground, and slip the rubber tubing over the stump. Then insert the glass tube in the rubber tubing and clamp to a ring stand. Fill the tube with water to the height of three feet, and mark the water level with a rubber band. Does the water rise in the tube? Where does the extra water come from?

b. Nearly fill the tube with water. Does the column still rise? What causes the pressure?

165. LEAVES

Leaves manufacture plant food from the raw materials, which have been gathered by the roots, and transported by the stems. Under the action of the sun's energy, water from the root, and carbon dioxide from the air, are combined to

form starch; while oxygen is given back to the air. The starch is then changed to grape sugar or glucose which combines with some of the elements brought from the ground, and forms proteids. Starch can only be produced in sunshine, although the formation of proteids may be performed in the dark.

Another function of the leaf, which is most important, is the very large evaporation of water from its surfaces. This aids capillarity and osmosis, in the rise of the sap, just as the burning of a lamp aids the upward motion of the oil, by removing the oil which is at the top. Evaporation from a leaf is called *transpiration*.

References: —

1. 1407 : 88-122. Leaves, — Structure and Functions.
2. 1503 : 122-141. Leaves and their Functions.
 - a. 1401 : 130-149. Leaves.
 - b. 1402 : 90-100. Leaves and Foliage.
 - c. 1403 : 24-48. Leaves.
 - d. 1404 : 163-224. Work of Leaves.
 - e. 1405 : 97-104. Leaves.
 - f. 1406 : 15-33. The Leaf — its Uses.
 - g. 1505 : 92-105. Leaves — Function or Work.
 - h. 1602 : 30-32. Leaves, Buds, Seeds.
 - i. 1604 : 157-176. Leaves and their Work.
 - j. 1609 : 306-314. Leaves.
 - k. 1611 : 72-80. How the Leaf Gets Food from the Air.

Experiment 78. — Transpiration.

Apparatus: Ring stand with clamp, beaker 100 c.c., glass tube $\frac{1}{2}$ " diameter, 8" long, beaker 200 c.c., tumbler.

Materials: Mercury, wax (beeswax 90 per cent, Venice turpentine 10 per cent), soil, olive oil.

a. Cut a small branch from a vigorously growing plant and seal it in one end of the tube with wax. Be careful not to

cover the cut part with wax, and do not cut the branch until it is needed. Place the other end of the tube, after filling it with cooled boiled water, below the surface of some mercury, in the beaker, and clamp the tube on the ring stand. (After Detmer.)

b. What happens? Is the mercury sucked up? See Experiment 44. Where does the water go to? What pressure is produced? See Experiment 42.

c. Place a geranium cutting in the large beaker, which should be three fourths full of moist soil. Cover the soil with olive oil and invert an ordinary table tumbler over the cutting. What do you notice after an hour? Does this explain (b)?

166. BUDS

Buds are of two classes, leaf and flower. Flower buds are only produced where there is a surplus of plant food beyond that which is necessary to supply the needs of life and growth. Anything which will check growth, without injuring the plant, will cause flower buds, and therefore more fruit. Advantage is taken of this fact where pruning is practiced.

The bud contains the characteristics of the whole tree, except that which is below the ground; and therefore we would expect that, if the bud could grow, it would be similar to the rest of the tree. Where grafting is practiced, this is made use of, since the addition of buds to another tree will produce branches which are similar to the bud. This is called *budding*.

References: —

1. 1407 : 80-87. Buds.
2. 1503 : 100-102. Buds.
3. 1605 : 227. Pruning.
4. 1605 : 230-233. Pruning.

- a. 1401 : 119-129. Buds.
- b. 1402 : 36-41. Winder Buds.
- c. 1403 : 19-23. The Opening of the Buds.
- d. 1405 : 86-96. Buds.
- e. 1406 : 173-186. Buds and Branches.
- f. 1502 : 175-179. Budding.
- g. 1505 : 111-120. Winter and Dormant Buds.
- h. 1603 : 54-61. Plant Propagation by Buds.
- i. 1606 : 163. Pruning *vs.* Training.
- j. 1609 : 283-286. Buds.

167. FLOWERS

The purpose of the flowers is that of reproduction. This is caused by the pollen of the same flower, or of other flowers, reaching the egg cells, which then grow into seeds, if plant food is supplied them. This *pollination*, as it is called, may be accomplished by wind, water, insects, gravity, or by a bending in of the part of the flower which carries the pollen. The latter is called *self-pollination*. *Cross-pollination*, where the pollen of one flower comes in contact with the egg cells of another flower, is productive of better results than those due to self-pollination.

Flowers are adapted to producing these results, in as many ways as possible, the color and perfume, as well as nectar of the flower, existing merely to attract insects. In some cases, the flowers have adapted themselves to the particular kind of insects of that locality, and have changed their shape so that the cross-pollination may be accomplished in the best way.

References: —

- 1. 1407 : 123-131. The Flower.
- 2. 1503 : 31-49. Flowers.
 - a. 1401 : 197-207. The Flower and its Organs.
 - b. 1402 : 128-134. Fertilization and Pollination.

- c. 1403 : 49-74. Flowers.
- d. 1403 : 74-78. Cross-fertilization.
- e. 1404 : 286-311. The Work of Flowers.
- f. 1405 : 159-167. Flowers and Reproduction.
- g. 1406 : 196-233. The Flower.
- h. 1603 : 44-53. The Flower.
- i. 1609 : 315-329. The Flower.
- j. 1611 : 91-99. The Flower and Fruit.

168. FRUITS AND SEEDS

After the seeds have become formed and have begun to grow, a certain amount of protection is necessary, as well as a plentiful supply of food. This is accomplished by a nut or fruit, or some other simple form of covering.

Since the crowding of plants beneath the parent plant would prevent proper growth, a seed dispersion is necessary. This is accomplished by some fruits themselves, such as the squirt cucumber; or it may be produced by elastic tissues of the seed pods, or through the agency of birds, animals, and water. Burrs and the stickers of foxtail are examples of transportation through other agencies, and the seeds sometimes cling to the feet of animals or of birds, and are carried some distance before being dropped. Wind transports fluffy and winged seeds.

When the seeds are in contact with moisture, osmosis takes place and water passes into the seed. See Section 119, Osmosis. After the absorption of water the growth depends upon warmth and plant food.

References: —

1. 1407 : 5-11. The Seed, its Germination and Storage of Food.
2. 1407 : 146-150. The Fruit.

3. 1503 : 50-65. Fruits.
4. 1605 : 47-55. Seeds.
5. 1702 : 235-240. Chemistry of Plant Growth, Seeds.
6. Farmers' Bulletin No. 157. The Propagation of Plants.
7. Farmers' Bulletin No. 329 : 15-16. Seed Selection.
 - a. 1401 : 5-13. The Seed and its Germination.
 - b. 1401 : 14-23. Storage of Food in the Seed.
 - c. 1401 : 221-227. The Fruit.
 - d. 1402 : 158-163. Dispersal of Seed.
 - e. 1403 : 90-94. What a Seed Is.
 - f. 1404 : 312-325. The Work of Fruits.
 - g. 1405 : 191-199. Seed Dispersion.
 - h. 1406 : 63-68. Fruits.
 - i. 1406 : 87-107. Seeds.
 - j. 1604 : 190-207. Blossom and Seed.
 - k. 1604 : 246-260. Seed Scattering.
 - l. 1604 : 261-276. Seed Carriers.

Experiment 79. — Seed Testing — Germination.

Apparatus: Shallow box filled with soil, or moistened saw-dust, divided into squares by strings crossing the box; beaker 100 c.c.

Materials: Seeds to be tested, 2 sheets blotting paper 6" x 6".

a. Place some seeds in a beaker full of water and see what happens to them in a few days. What do seeds need in order to sprout?

b. Place some seeds in some dry soil. Do they sprout?

c. Place some seeds one fourth of an inch below the surface of the soil in the little squares, in the box. Number the squares and make a note of the seeds used. See how many germinate. Corn may be tested in this manner and the proper kind of corn selected for planting.

d. Seeds may be sprouted by being kept between two pieces of moistened blotting paper. Try it.

169. FLAVORING EXTRACTS AND PERFUMES

To quote from the standards established by the Secretary of Agriculture in 1906: "A flavoring extract is a solution in ethyl alcohol of the proper strength, of the sapid and odorous principles derived from an aromatic plant, or parts of the plant, with or without its coloring matter, and conforms in name to the plant used in its preparation." Again quoting: "The two principal flavors are vanilla and lemon, it being estimated that 95 per cent of the flavoring extracts manufactured are of these two varieties. With few exceptions the other flavoring extracts are artificial, it being impossible to manufacture an acceptable extract from the fruit itself. Orange, peppermint, and wintergreen extracts are among the exceptions to this rule, while strawberry, pineapple, peach, and some others are artificial."

Vanilla extract may be prepared by grinding vanilla beans in a meat chopper and allowing the mass to soak in 50 per cent pure grain alcohol, in a stoppered bottle, for a few days. This will produce a delicately flavored extract at a moderate price.

Chopped-up orange peeling, or lemon peeling, soaked in 85 per cent pure grain alcohol, will produce satisfactory orange or lemon extracts.

Many perfumes may be made by chopping the material which has the desired odor and allowing it to soak in 95 per cent alcohol for several days.

References: —

1. Reprint from Yearbook of Department of Agriculture for 1908: The Manufacture of Flavoring Extracts.

Experiment 80. — To Make Lemon Extract.

Apparatus: Bottle with glass stopper, knife, funnel.

Materials: Alcohol 95 per cent, lemon, filter paper.

a. Carefully peel the outside of the lemon, removing only the colored part and cutting off as little of the white part as possible. Put the cuttings into the bottle and cover with about twice their volume of 95 per cent alcohol. Shake the bottle and then allow it to stand for two days. Filter into a clean dish and the extract is ready for use. See reference for full directions for making other extracts.

170. PLANT FOOD—II

This subject has been covered in the consideration of fertilizers, humus, irrigation, drainage, the work of roots, and the work of leaves. Thus a general review of the whole subject can be taken up and discussed.

The food absorbed by plants is not all utilized immediately, but may be stored, as, for instance, in potatoes, turnips, beets, onions, and in some stalks. The food is used for growth as well as for fruit and seed production. If the amount of food is reduced, the growth of fruit is increased, but at the cost of the plant growth. Reducing the growth of the plant also increases the yield of fruit. Therefore pruning is beneficial.

Weeds, through a long process of evolution, have become adapted to living better than any beneficial crop. Therefore they are hard to kill, but their destruction is necessary, since they remove large quantities of plant food and water from the soil.

References:—

1. 1407:8-11. The Storage of Food in the Seed.
2. 1503:95-96. Food Storage in Plants.
3. 1601:147-153. Osmosis and Diffusion in Plant Feeding.
4. 1605:68-71. The Manufacture of Food Materials.
5. 1702:242-246. Movement of Plant Juices—Chlorophyll and Protoplasms.
6. Farmers' Bulletin No. 28. Weeds and How to Kill Them.

7. Farmers' Bulletin No. 44: 11-22. Fertilizing Material—Plant Food.
8. Farmers' Bulletin No. 181. Pruning.
 - a. 1402: 72-73. The Food Material.
 - b. 1402: 74-84. The Making of Living Matter.
 - c. 1603: 41-42. Feeding from the Air.
 - d. 1603: 31-33. Feeding from the Soil.
 - e. 1611: 81-90. How the Plant Uses the Food it Makes.
 - f. 1612: 44-51. How Plants Feed.

171. THE PROPAGATION AND BREEDING OF PLANTS

Propagation means the production of new individuals. It may take place through the agency of roots, cuttings, leaves, buds, grafts, and seeds.

By plant breeding is meant the production of plants having new characteristics, which may be unlike any of the ancestors. Cross-pollination, accomplished and regulated by man, may produce these new plants. After proper selection is made of the plants having the desired characteristics, and these plants are bred from, there can gradually be produced plants having a certain feature, to any desired degree. Nature has done the same, but since nature necessarily must depend to such a great extent upon accidental cross-pollination, and since many accidents may happen to the new plants, the results have not been as rapid as when the work has been carried on by man. Also, in nature, there has always been a survival of the fittest; there is a continual fight for existence, and the new plant may not be as well adapted to maintain its existence as some of the older forms. With man, since it is the plant that is desired, the environment is adjusted to it, and the new species has the best chance of living. It must be remembered, in the experiments with plants, that man merely directs the course that nature would take if given opportunity; but by

proper direction accidents are avoided and the goal is reached much more quickly.

References:—

1. 1407: 500-513. Plant Breeding.
2. 1503: 116. Budding and Grafting.
3. 1605: 36-55. Propagation of Plants.
4. Farmers' Bulletin No. 157. The Propagation of Plants.
5. Farmers' Bulletin No. 409. School Lessons on Corn.
 - a. 1402: 20-22. Propagation of Plants.
 - b. 1404: 19-29. Propagation by Means of Roots and Stems.
 - c. 1502: 155-180. Propagation.
 - d. 1505: 121-128. Bud Propagation.
 - e. 1606: 112-123. Growth of Plants.
 - f. 1606: 132-140. Propagation.
 - g. 1608: 148-156. Propagation of Plants.
 - h. 1609: 314-315. Modes of Reproduction.
 - i. 1611: 91-105. How Plants are Propagated.

172. PLANTS — FORESTRY

While the effects of climate, soil, and water upon plants and all vegetation are very great, yet plants, in large masses, have a reciprocal effect upon these very factors which determine a plant's life. Forestry, or a study of the needs and results of forest growth, is most important. The forest should also be considered as a crop, the same as wheat, barley, or any other vegetable growth intended for the use of mankind.

Forests regulate the flow of streams, by preventing a too rapid run-off of rain water. For the same reason, they cause more water to enter the earth, and there is less erosion of the good land. The decaying leaves and branches produce humus, and thus the soil is enriched where forests remain. More than this, forests prevent high winds, moisten the air, and actually change the climate of a locality to a very marked

degree. Fog condenses on the foliage and drips to the ground, adding a little to the streams.

The greatest danger to forests is that of fire. After this come destructive lumbering, trampling and browsing by grazing animals, wind, and fungi.

References: —

1. 1304: 349-350. Forest Growing.
2. 1407: 490-492. The Forest Region.
3. 1503: 116-117. Forestry and the Value of Trees.
4. 1605: 216-226. The Wood Crop.
5. Farmers' Bulletin No. 173. A Primer of Forestry — The Forest.
6. Farmers' Bulletin No. 358. A Primer of Forestry — Practical Forestry.
7. Farmers' Bulletin No. 134. Tree Planting on Rural School Grounds.
8. Farmers' Bulletin No. 181. Pruning.
9. Farmers' Bulletin No. 228. Forest Planting.
10. Farmers' Bulletin No. 423. Forest Nurseries for Schools.
11. Forest Service, Circular 130. Forestry in the Public Schools.
12. Forest Service, Bulletin 36. The Woodsman's Handbook.
13. Reprint from Yearbook of Department of Agriculture for 1903. The Relation of Forests to Stream Flow.
14. Reprint from Yearbook of Department of Agriculture for 1905. How to Grow Young Trees for Forest Planting.
 - a. 1402: 222-223. Rotation of Forests.
 - b. 1502: 365-391. Forestry.
 - c. 1606: 3. Forestry Defined.

173. LOWER FORMS OF PLANT LIFE — BACTERIA, MOLDS, AND MILDEW

Bacteria, as well as molds and mildew, are minute plants, although they were long considered as having animal life. Their greatest peculiarity is the method by which they are

propagated. This takes place by means of spores in the case of molds, mildews, and some bacteria, and by means of division with most bacteria.

Bacteria are often mentioned only as disease bacteria. We must not get the idea that all bacteria are bad, for such is not the case. There are only about twenty-two species that are harmful to man, while there are several thousands of the kind which aid man in many ways. It is probable that the white corpuscles of the body are bacteria, whose function it is to protect us from the inroads of the harmful bacteria.

Other bacteria are used in the animal system to cause digestion, and it is probable that digestion would be absolutely impossible, if it were not for these agents. Bacteria enable plants to absorb nitrogen from the air; they cause the decay of animal matter, as well as vegetable matter, so as to render proper food supplies available for plants. In fact, their advantages are so great that they cannot be enumerated in this place. Under agriculture, mention has been made of the importance of the nitrogen-fixing bacteria, as well as the bacteria of decay.

References: —

1. 1407 : 228-238. Bacteria.
2. 1501 : 382-390. Bacteria and Disease.
3. 1503 : 168-172. Bacteria.
4. 1601 : 124-130. Nitrogen-fixing Bacteria.
5. 1605 : 97-99. Life in the Soil.
6. 1901 : 1-12. Introduction to the Study of the Lower Plants.
7. 1901 : 12-39. General Nature of Molds.
8. 1901 : 100-114. General Nature of Bacteria.
9. 1901 : 124-131. Dead Food Bacteria.
10. 1901 : 203-211. Disease Bacteria.
11. 1901 : 212-240. Prevention of Contagious Diseases.

12. Farmers' Bulletin No. 317: 27-28. "Starters" for Ripening Cream.
13. Farmers' Bulletin No. 348. Bacteria in Milk.
 - a. 1401: 336-344. Parasites.
 - b. 1404: 361-408. Plants which cause Fermentation, Decay, and Disease.
c. 1502: 457-477. Flowerless Plants.
 - d. 1611: 183-226. Friends and Foes of the Plant.
 - e. 1902: 9-21. General Character of Bacteria.
 - f. 1903: 13-25. General Characteristics of Bacteria.
 - g. 1903: 168-174. Nitrification due to Bacteria.
 - h. 1904: 18-20. Bacteria.

174. FERMENTATION — YEASTS

Yeasts are small plants which live upon starches and sugars, changing them into alcohol and carbon dioxide. The highest amount of alcohol which can be produced by yeasts is about 14 per cent, as yeasts cannot grow if there is more than this percentage of alcohol present. If a larger percentage of alcohol is desired, as in whisky or brandy, the fermented material must be distilled. The above is called *alcoholic fermentation*.

Yeasts reproduce themselves by budding; that is, a small bud appears upon the main cell and, becoming larger, breaks off, as a perfect plant.

There is another kind of fermentation which is called *acid fermentation*. Bacteria are the cause of this, and examples of bacterial fermentation are the souring of milk and the changing of cider, or wine, to vinegar.

References: —

1. 1407: 231-232. Fermentation.
2. 1501: 41-48. Fermentation and Alcohol.
3. 1503: 166-168. Yeasts and Fermentation.

4. 1702: 318-324. Fermentation.
5. 1703: 194-195. Fermentation.
6. 1901: 56-85. Yeasts.
7. Farmers' Bulletin No. 175: 6. Causes of Fermentation.
8. Farmers' Bulletin No. 348. Bacteria in Milk.
 - a. 1405: 232-234. Yeast, its Food and Growth.
 - b. 1502: 465-466. Yeasts.
 - c. 1507: 62-67. Fermentation and Yeast.
 - d. 1603: 100-116. Yeast and Bacteria — the Diseases of Plants.
 - e. 1704: 260-261. Fermentation.
 - f. 1707: 459-461. Fermentation.
 - g. 1708: 406-410. Fermentation and Life.
 - h. 1711: 291-293. Fermentation.
 - i. 1712: 281-292. Fermentation.

175. ALCOHOL FOR PURPOSES OF ENERGY

The United States Government has removed the internal revenue tax on alcohol, provided it is used for purposes of lighting, heating, cooking, or power. Under these circumstances the alcohol must have something added to it to render it unfit for drinking or as a medicine. The process is called *denaturing*, and the alcohol is said to be denatured. For denaturing purposes, wood alcohol, benzine, and pyridin are used.

In addition to the removal of the tax, the government permits the establishment of distilleries, under proper supervision, and the manufacture of alcohol may be carried on at any place. Alcohol may be produced from many of the waste products of the farm, and thus the farmer is especially benefited by the removal of the tax on alcohol. A good distillery can be established on the coöperative basis, and can run continually in every small community. Any vegetables,

or stalks of crops, which contain starch or sugar, are sources of alcohol.

Alcohol burns with a nearly colorless flame, without soot; that is, there is complete combustion. See Section 4, Combustion. Therefore the flame is very hot. To obtain light, it is necessary to use a covering for the flame, which is rendered white-hot, but which does not burn. These coverings are made of rare earths and are called *incandescent gas mantles*.

Gasoline engines can be adapted to the use of alcohol, and special stoves are now made which burn alcohol in the place of gasoline. Alcohol, in the open market, is more expensive than gasoline, but it has some advantages in convenience and safety. Nevertheless, since alcohol is made from material which would otherwise be wasted, there is a decided gain for the farmer who either makes his own alcohol, or who combines with his neighbors to maintain a coöperative distillery.

References: —

1. 1703 : 414-415. Preparation of Ethyl Alcohol.
2. Farmers' Bulletin No. 410. Potato Culls as a Source of Industrial Alcohol.
3. Farmers' Bulletin No. 429. Industrial Alcohol.
 - a. 1701 : 401-405. Alcohol.
 - b. 1704 : 209-214. Alcohol and Distillation.
 - c. 1705 : 155-156. Alcohols.
 - d. 1706 : 408-411. Alcohols.
 - e. 1707 : 471-472. Alcohols.
 - f. 1708 : 403-404. Alcohols.
 - g. 1709 : 381-384. Alcohols.
 - h. 1711 : 290-291. Alcohols.
 - i. 1712 : 273-276. Alcohol. Distillation and a Test for Alcohol.

Experiment 81. — Sources of Alcohol.

Apparatus: Same as in Experiment 17, six 6"×8" battery jars.

Materials: Grape sugar, molasses, apples, potatoes, rice, beets, starch, grape juice, corn stalks, yeast cakes.

a. Make dilute solutions of the sugar and molasses and pastes, thinned in water, called *mashes*, of as many of the other materials as can be obtained. Add an amount of yeast, or yeast sponge, equal to about 10 per cent of the mash, in each case. Warm gently to 70° F., and allow fermentation to take place for twenty-four hours.

b. Distill at a temperature of 180° F., and burn the alcohol. Judging from your own experience, which material produces the most alcohol?

176. LOWER FORMS OF PLANT LIFE — FUNGI, RUSTS, MUSHROOMS, ETC.

Many of these lower forms of plant life are not supplied with chlorophyll and cannot produce their own food. Thus they must become parasites and depend upon other plants and trees for their support. They may be considered as reducing the amount of organic matter, and not increasing it. They are useful, however, in hastening the decay of dead vegetable matter.

References: —

1. 1407:227. The Fungi and What They Are.
2. 1503:159-166. Fungi, Parasites, Saprophytes.
3. 1605:250-254. Fungus Diseases—Scab, Smut, and Rust.
4. Farmers' Bulletin No. 204. Cultivation of Mushrooms.
5. Farmers' Bulletin No. 243. Fungicides.
 - a.* 1401:274-277. Fungi.

- b. 1402 : 180-185. Fungi.
- c. 1405 : 234-236. Fungi and their Mode of Life.
- d. 1502 : 435-456. Ferns, Mosses, Liverworts, Lichens, Algae, Mushrooms.
- e. 1504 : 191-193. The Mushroom.
- f. 1505 : 187-195. Fungi.
- g. 1505 : 195-199. Lichens, Liverworts, and Mosses.
- h. 1904 : 8-12. The Relation of Fungi to Other Plants.

177. PROTOZOA AND AMOEBAE

The *protozoa* are the smallest of the microscopic animals, and the best known of them are the *amœbae*. These are about one one-hundredth of an inch in diameter and consist, like other protozoa, of a single cell composed of protoplasm.

The amœbae move from place to place by means of flowing and contracting. They feed by absorption; that is, they surround their food, and leave the undesired particles as they move on. Water is also absorbed in the same way. Thus the amœbae grow by the accumulation of food.

Reproduction is effected by the central part, or nucleus, dividing into two separate parts; the whole animal then elongates and separates between the two nuclei. Then there are two amœbae.

References :—

- 1. 1407 : 158-159. The Amœba.
- 2. 1501 : 10-11. The Amœba.
- 3. 1503 : 179-186. Protozoa.
- a. 1504 : 1-22. Amœba.
- b. 1504 : 305. A List of Protozoa.
- c. 1505 : 10-16. Protozoa — One-celled Animals.
- d. 1508 : 116-119. Activities of One-celled Animals.
- e. 1509 : 4-9. A Simple Type of Animal.
- f. 1510 : 9-11. Irritability, Assimilation, and Reproduction in Amœba.
- g. 1512 : 286-306. Protozoa.

178. INSECTS AND THE SMALLER ANIMALS

Insects are air-breathing animals with six legs, and with their bodies divided into three separate parts. Most of the insects are harmful to man, since they either live upon the bodies of animals, or vegetable life, which are valuable to man. Some insects consume decaying animal and vegetable matter, and enrich the soil by increasing the humus.

Most insects pass through several stages: the egg, worm, cocoon, or a dormant state, and finally the mature insect. The worm stage is the one in which the most damage is accomplished. The destruction of the insect in the dormant state prevents a large increase of its kind, because it is the moth which lays the eggs in very large numbers.

References: —

1. 1304 : 359. Homes of Animals.
2. 1407 : 422-425. Insects Useful to Plants.
3. 1503 : 227-255. Insects.
4. 1605 : 255-266. Insects and their Control.
5. Farmers' Bulletin No. 127. Important Insecticides.
6. Farmers' Bulletin No. 145. Carbon Bisulphide as an Insecticide.
7. Farmers' Bulletin No. 155. How Insects Affect Health in Rural Districts.
8. Farmers' Bulletin No. 196. Usefulness of the Toad.
 - a. 1502 : 62-89. Insects of the Household.
 - b. 1505 : 63-85. Insects.
 - c. 1508 : 57-67. Some Insects Classified.
 - d. 1602 : 143-151. Animals that Destroy Insects.
 - e. 1603 : 118-146. Orchard, Garden, and Field Insects.
 - f. 1604 : 60-89. Field Laborers.
 - g. 1604 : 227-245. Guests, Welcome and Unwelcome.
 - h. 1604 : 300-312. Friends and Foes.
 - i. 1604 : 313-336. Nature's Militia.
 - j. 1904 : 103-109. Disease Carried by Insects.

179. THE STINGS OF INSECTS

The pain caused by stings is due chiefly to *formic acid* or to some irritant which is injected; that is, the effect is chemical. Ammonia, since it neutralizes an acid, is good to allay the pain.

There is a secondary effect, however, for which the insects are not responsible, and which is due to the bacteria or protozoa which they inject at the time they sting. Yellow fever and malaria are caused only by the bite of a certain kind of mosquito which injects protozoa. Similarly, the "sleeping sickness" is due to another species of protozoa which is injected by the bite of a fly, similar to the tsetse fly.

We can reduce the number of mosquitoes and finally exterminate them from a given locality by preventing the growth of their larvæ, commonly called "wrigglers." This can be accomplished by pouring crude oil upon the surface of the water where they swarm.

References: —

1. 1304 : 170. Swamps and Malaria.
2. 1501 : 154. Insects' Stings and Bites.
3. 1503 : 185-186. Mosquitoes and Flies Transmit Disease.
4. 1901 : 214-220. Malaria and Yellow Fever — Mosquitoes.
5. Farmers' Bulletin No. 155. How Insects Affect Health in Rural Districts.
 - a. 1308 : 143-145. Man's Enemies.
 - b. 1505 : 160-161. Mosquito Fevers.
 - c. 1506 : 269. Malaria from Mosquito Bites.
 - d. 1507 : 132-135. Malaria and Mosquitoes.
 - e. 1509 : 189. Malaria and Mosquitoes.
 - f. 1904 : 103-109. Malarial Fever and Yellow Fever.
 - g. 1904 : 110-116. Mosquitoes and their Control.

180. ANIMAL LIFE — DISTRIBUTION

The distribution of animal life is regulated, or governed, by climate and the physiography of the land. Some animals are fitted to live in warm, and others in cold, climates. Each class is thus confined to its own locality. Mountains, oceans, large bodies of water, and deserts, prevent the distribution of animals, and we would expect to find distinct species in isolated districts. We have learned from travelers that this is the case.

References: —

1. 1304: 353-366. Distribution of Animals.
2. 1503: 312-316. Adaptation of Mammals.
- a. 1204: 12-16. Geological Control of Life.
- b. 1301: 165-186. Distribution of Animal Life and Plants.
- c. 1302: 364-367. Animal Geography.
- d. 1303: 332-372. Distribution of Animals, Plants, and Man.
- e. 1305: 313-327. The Various Forms of Life.
- f. 1305: 328-349. The Distribution of Life.
- g. 1306: 135-148. Geographic Distribution of Animals and Plants.
- h. 1307: 302-312. The Dispersal of Life.
- i. 1308: 120-123. The Organic Environment.
- j. 1309: 292-310. Distribution of Animal Life.
- k. 1310: 473-480. The Environmental Relations of Animals.
- l. 1311: 332-345. Geographic Conditions of Life.
- m. 1312: 400-439. Geography of Plants and Animals.
- n. 1508: 236-242. The Distribution of Animals.

181. THE INVERTEBRATES

All animals come under two general heads: *Invertebrates* and *Vertebrates*. The latter have a backbone made up of sections called *vertebræ*, while the former either have no bony

structure or are covered with some kind of shell or horny substance.

The common invertebrates are worms, insects, and the crustaceans, or shellfish. See Section 178, Insects and Smaller Animals. Worms are very beneficial to the soil. See Section 131, Disintegration due to Plant and Animal Life.

References: —

1. 1304 : 359. *Home of Invertebrates.*
2. 1503 : 191-193. *Sponges.*
3. 1503 : 208-214. *Worms.*
4. 1503 : 215-226. *Crustaceans.*
5. 1503 : 256-258. *Spiders.*
6. 1503 : 259-269.
 - a. 1504 : 304-306. *The Chief Divisions of the Animal Kingdom.*
 - b. 1505 : 8-9. *Method of Classifying Animals.*
 - c. 1505 : 17-21. *Sponges.*
 - d. 1505 : 42-50. *Worms.*
 - e. 1505 : 51-61. *Crustaceans.*
 - f. 1508 : 1-3. *Animals Classified.*
 - g. 1508 : 243-254. *Animal Relationships.*
 - h. 1512 : 284-285. *Classification of Animals.*

182. ANIMAL LIFE — FISHES, ANIMALS, AND BIRDS

It is quite likely that the first living beings of any size were water animals, although not, perhaps, fishes.

Some of these water animals went upon the land, and by persistent habits, through untold ages, became adapted to life on land. Others developed into birds, or at least flying animals. Those species which became best adapted to any particular kind of life survived and produced their kind. The others died. Thus, starting as life in the water, all the present forms, as well as many extinct species, have developed.

References:—

1. 1304:359. Homes of Animals.
2. 1503:271-277. Fishes.
3. 1503:292-306. Birds.
4. Farmers' Bulletin No. 54. Some Common Birds.
5. Farmers' Bulletin No. 383. How to Destroy English Sparrows.
 - a. 1502:305-307. Our Common Birds.
 - b. 1502:347-363. Taming and Feeding Birds.
 - c. 1502:405-433. Miscellaneous Animals.
 - d. 1504:141-147. Creation and Evolution.
 - e. 1505:109-121. Fishes.
 - f. 1505:126. Animal Life Originated in the Sea.
 - g. 1505:150-165. Birds.
 - h. 1508:1-3. Animals Classified.
 - i. 1508:169-177. The Structure and Activities of a Fish.
 - j. 1508:197-210. Birds.
 - k. 1512:154-167. Fishes.
 - l. 1512:208-221. Birds.

183. ANIMAL LIFE — MAN

Man is the most highly developed animal that exists on the earth, or ever has existed. In man we have the highest form of brain, and the mind has made its appearance. The one distinction between man and the other animals is that man has a mind and can direct his own progress and advancement. With other animals accident plays a large part, but is nearly eliminated in man, on account of this mind and the possible education which he may receive. Mental development, then, is the separating feature between man and other animals, as far as the physical life goes.

See Section 198, The Mind, and Section 201, Man's Place in Nature..

References: —

1. 1205 : 443-449. Man and his History.
2. 1304 : 367-392. Man and Nature.
 - a. 1206 : 438-443. Advent of Man.
 - b. 1302 : 383-392. Geography of Man.
 - c. 1305 : 326-327. Development Theory.
 - d. 1306 : 407. Man and Nature.
 - e. 1307 : 335-351. Man.
 - f. 1308 : 126-142. Human Adaptation — Environment of Influences.
 - g. 1309 : 311-321. Man.
 - h. 1311 : 346-370. The Earth and Man.
 - i. 1312 : 439-447. Distribution of Mankind.
 - j. 1313 : 229-231. The Historical Distribution of Peoples.
 - k. 1508 : 211-234. Man's Near Relations.

184. THE LIFE PROCESSES

The simple cell is the foundation of all life. Thus the life of a plant, or an animal, is composed of the lives of an almost infinite number of cell lives. What affects the cell affects the whole plant or animal, and therefore a better understanding of the elementary life is necessary if we are to comprehend the life processes of higher plants and animals. Just as the molecule is the smallest portion of matter which can exist alone, so the cell is the smallest portion of matter which can have life. The cell is composed of protoplasm.

References: —

1. 1407 : 156-158. The Simplest Living Unit a Cell.
2. 1501 : 9-20. Cells.
3. 1501 : 22-30. Elements of the Body.
4. 1503 : 23-30. Protoplasm and the Cell.
5. 1503 : 183-184. The Cell a Unit.
6. 1702 : 243-244. Protoplasm.
 - a. 1406 : 11. The Cell.

- b. 1504 : 61-70. The Cell the Foundation of Life.
- c. 1505 : 10-16. Protozoa (One-celled Animals).
- d. 1507 : 17-24. Structure, Life, and Work of Cells.
- e. 1509 : 1-9. Plant and Animal Life in the Simplest Forms.
- f. 1510 : 9. Meaning and Importance of the Cell.
- g. 1511 : 5-6. Cell Structure.
- h. 1512 : 301. The Cell.
- i. 1704 : 281-286. Physiological Chemistry.
- j. 1708 : 409-411. Chemistry of Life.

185. THE BONES, OR FRAMEWORK

Just as in plants the stems serve to hold up the body, so in animals some stiff structure is necessary. The complete framework is called the *skeleton*, and its parts are called *bones*. Bones are hollow in order to obtain the greatest strength with the least amount of material, and the cavity is used to supply the bones with nourishment.

Most animals have their framework covered with flesh, but some have a stiff outside covering which serves the same purpose as the skeleton, and acts as a protection against enemies. See Section 181, The Invertebrates.

In order to allow free movements, the bones, or coverings, are jointed, being held together by cartilage. These places of bending, or yielding, are called *joints*.

References : —

- 1. 1501 : 357-363. The Bones.
- 2. 1501 : 364-369. The Joints.
- 3. 1503 : 371-379. Bones and Joints.
 - a. 1505 : 29-38. The Skeleton.
 - b. 1506 : 191-202. Osseous System of Bones.
 - c. 1509 : 10-25. The Skeleton.
 - d. 1510 : 103-111. The Skeleton and the Muscles.
 - e. 1511 : 11-43. The Osseous System, or Skeleton.

186. THE LEVER AND ITS ADVANTAGE

Any body which moves on a pivot, and has one part farther away from the pivot than another part, is a lever. Any force which is applied to the end farthest from the pivot, will cause the shorter end to exert a greater force. The relation between the resulting force and the applied force is the *advantage of the lever*.

The most common example of the lever, which has a large advantage, is the crowbar. If a man desires to pry up a rock, he forces the bar under it and then pushes down on the longer end. Here there is a short length of the bar under the rock; the bar is pivoted on the ground near the rock, and the longer portion of the bar, upon which the force is applied, extends upward. If the part of the bar which is beyond its resting point, or pivot, is one tenth of the longer end, a man who weighs one hundred and fifty pounds can move a rock weighing ten times his own weight, or fifteen hundred pounds. The advantage of the lever, in this case, is ten.

Sometimes the force is applied to the shorter end of the lever in order to obtain greater velocity at the other end. This is obtained at the expense of force; that is, the force applied must be greater than the force which is obtained at the longer end. The force multiplied by the numerical measure of the distance through which it acts is equal for both ends of the lever. The bones and joints of animals form levers of this style, and since the muscle acts on the shorter arm of the lever, there is a mechanical disadvantage. That is, the muscle must pull much harder than the force which is being overcome when the animal moves. Thus, in holding at arm's length a weight of twenty pounds, the muscle of the arm is

obliged to contract with a force of over two hundred pounds.

The lever is the fundamental basis for many machines, and the moving pulley and the gear are only special forms of levers. The human and other skeletons contain many examples of the lever.

References: —

1. 1803 : 151-154. The Lever.
- a. 1509 : 53-55. Kinds of Levers.
- b. 1801 : 83-85. The Lever, its Advantage and Use.
- c. 1802 : 146. The Lever.
- d. 1804 : 102-104. Experiments with the Lever.
- e. 1805 : 84-88. The Lever and its Law.
- f. 1806 : 65-68. The Lever, Straight and Circular.
- g. 1807 : 123-127. The Lever and its Applications.
- h. 1808 : 88-93. The Lever—Straight, Bent, Compound.
- i. 1809 : 81-83. The Lever and its Applications.
- j. 1810 : 2-7. Levers.
- k. 1811 : 355-356. The Lever.

Experiment 82. — The Lever.

Apparatus: A stick $36'' \times 1'' \times \frac{1}{2}''$, with holes bored every inch through the middle of the flat side, ring stand, nails to fit holes, 3 double hooks of wire to hook over both ends of a nail when it is pushed through a hole in the stick, having a third hook opposite the double part, 12 iron balls all of the same size, with hooks on opposite sides.

a. Push a nail through the middle hole, and support the stick, by one hook, on a ring stand. Push a nail through the first hole to the left and another nail through the second hole to the right. How many more balls can be hung on one side than on the other? On which side is the greater weight? Double the number of balls on one side. How many times the original number can now be supported on the other side?

b. Repeat (a), but go out to the fifth hole on one side. Make a table of your results in (a) and (b).

c. Try some original experiment with this lever, and write out what you did and the results which you obtained.

d. Describe a method of weighing ten pounds with a one-pound weight and a stick.

187. THE MUSCLES

Movement, even with the joints, would be impossible, if it were not for the *muscles*, which, by contracting or relaxing, shorten and lengthen, thus moving the parts to which they are attached. Muscles form the flesh, or meat, of animals, and are the parts which are eaten as animal food. Exercise hardens the muscles, and it can be readily seen that animals intended for the food of man should not be allowed to exercise more than enough to maintain their health. All muscles work at a mechanical disadvantage. See preceding section.

A uniform development of the muscles of our bodies is desirable, and this can only be secured by regular and special exercises. A person's usual employment generally develops a certain set of muscles, and unless he artificially exercises the other muscles, he is liable to become deformed.

References: —

1. 1501 : 371-379. *Muscles and Exercise.*
2. 1503 : 362-367. *The Muscles.*
 - a. 1505 : 39-50. *The Muscles.*
 - b. 1506 : 203-212. *The Muscular System.*
 - c. 1507 : 273-288. *Muscles.*
 - d. 1509 : 40-49. *Muscles and Tendons.*
 - e. 1510 : 99-102. *The Muscles.*
 - f. 1511 : 47-72. *The Muscular System.*

188. THE BLOOD

The blood serves as a carrier of food and oxygen to all parts of the body. It is the builder and also the cleanser of the system. In the digestive organs the blood takes up the newly prepared body food and distributes it to all the living cells, in every part of the body. The oxygen, which the blood receives in the lungs, is also carried to every cell, by means of red corpuscles, where it burns up the waste material, changing it into such a shape that it can be carried to the lungs, where it is exhaled as carbon dioxide and decayed animal matter, and to the perspiratory glands, where it is carried off mechanically. The kidneys absorb other waste from the blood.

The white corpuscles serve as protective agents, destroying bacteria which enter through a broken skin.

References: —

1. 1501 : 156-161. The Blood.
2. 1501 : 161-169. The Heart.
3. 1503 : 344-349. The Blood.
4. 1503 : 392-394. The Human Kidney.
 - a. 1505 : 52-69. The Circulation.
 - b. 1506 : 106-113. The Blood and its Uses.
 - c. 1507 : 126-127. White Blood Corpuscles.
 - d. 1509 : 135-152. The Circulation of the Blood.
 - e. 1509 : 196-199. The Removal of Waste Products.
 - f. 1510 : 67-86. Circulation.
 - g. 1511 : 75-105. The Blood and its Circulation.

189. RESPIRATION

The material in the blood must receive a sufficient supply of oxygen in order that the waste material may be consumed. The lungs supply this need, and man inhales about thirty

cubic inches of air, eighteen times a minute, from which part of the oxygen is absorbed. All living beings, except some microscopic forms, require oxygen. Even fishes absorb it from the air which is dissolved in the water, and will die in water from which the air has been removed. Plants also breathe, but this absorption of oxygen must not be confused with the work of the leaves.

While we breathe only about thirty cubic inches per breath, this does not nearly represent the capacity of the lungs, which is about three hundred and thirty cubic inches. It is easy to see, then, that in ordinary breathing we do not supply our lungs with fresh air, but merely dilute the vitiated air that is already there. If we wish to be in a healthy condition, we must realize, then, that at several periods during the day we should make an effort to exhale all the air possible from our lungs and then to take a very deep breath, repeating this four or five times. The effect on the health of a person who will do this every few hours, out in the fresh air, is quite marvelous. Part of the advantage of vigorous exercise is due to the fact that we must breathe more deeply when exercising than we do ordinarily. Although some of us are not strong enough to take violent exercise, yet we can all breathe deeply at some period during the day.

Human beings breathe in two ways. Women breathe from the chest, men from the abdomen. It is probably true that both methods are wrong. The woman exercises the upper part of her lungs, and the man the lower part. It does not tend to produce even development, and both ways leave part of the lungs unaffected. Both ways tend to produce disease of the lungs, since it is only by the vigorous use of all parts of our body that we can maintain our health. Nature always takes away from us what we do not use. The proper

way to breathe is to have both the chest and the abdomen partly inflated when each breath is taken.

References: —

1. 1407 : 110-112. Respiration in Plants.
2. 1501 : 192-204. The Lungs.
3. 1503 : 380-390. Respiration.
 - a. 1404 : 194-195. The Breathing of Plants.
 - b. 1505 : 72-88. Respiration and Ventilation.
 - c. 1506 : 138-149. The Lungs and Breathing.
 - d. 1507 : 190-210. The Mechanism and Chemistry of Respiration.
 - e. 1509 : 165-178. Respiration.
 - f. 1510 : 23-44. Respiration.
 - g. 1511 : 107-121. The Respiratory Organs.

190. DANGERS OF VITIATED AIR

The air of an insufficiently ventilated room contains, after occupancy, a considerable quantity of carbon dioxide, particles of animal tissue which have been expelled from the lungs, disease germs, and unpleasant if not dangerous odors from perspiration. The odor of the air in a room is a good index of its impurity, although the odor, in itself, may be harmless. A test for the amount of carbon dioxide present likewise indicates the degree of vitiation, six parts in ten thousand being as much as can be safely endured, although this amount of carbon dioxide alone is harmless.

Vitiated air tends to produce a poor appetite, weakens the constitution, and may lead to consumption. The effects of bad air are slow in their results and too often are not recognized as due to lack of sufficient ventilation. Many a vacation trip owes all its beneficial results to the fact that fresh air was unlimited. Consumption is being cured by pl-

fresh air by night as well as by day. See Section 19, Ventilation and Heating of Buildings.

References:—

1. 1501 : 223-230.	Dangers of Impure Air.
2. 1503 : 387-388.	Need of Ventilation.
3. 1702 : 66-71.	Air and Ventilation.
4. 1710 : 16-22.	Substances in the Air.
5. 1710 : 40.	Dangers from Air Vitiation.
6. 1901 : 230-234.	The Air and Disease.
a. 1505 : 80-86.	Hygienic Habits of Breathing.
b. 1506 : 153-156.	Impurities in the Air.
c. 1507 : 206-209.	Evils of Indoor Life.
d. 1509 : 182-184.	Effects of Respired Air.
e. 1509 : 189-192.	Dust and Disease.
f. 1510 : 40-42.	Hygiene of Respiration.
g. 1511 : 128-129.	Object and Need of Ventilation.
h. 1904 : 63-67.	Care of Consumptives.
i. 1905 : 33-38.	Impurities in Air, their Effects and Tests.

Experiment 83.* — Test for Bad Air.

Apparatus: A twenty-ounce glass stoppered bottle, glass measure graduated in cubic centimeters, medicine dropper graduated to hold one third of a cubic centimeter.

Materials: Limewater solution (pure water left in contact with slaked lime until saturated. Dilute the clear decanted liquid with 99 times its own volume), phenolphthalein solution (dissolve one part of phenolphthalein in 500 times its own weight of 50 per cent alcohol).

a. Fill bottle with pure water, and empty it in the place where the air is to be tested. This will insure the bottle being filled entirely with the air of the room. Add 10 c.c. of lime-water solution and one-third c.c. of phenolphthalein solution,

* After Dr. J. B. Cohen, modified.

stopper, and shake. If the red color disappears in three minutes or less, the air is unfit to breathe.

The following table is taken from book No. 1905.

"The percentage of carbon dioxide may be estimated from the time which it takes to decolorize the phenolphthalein as follows:—

TIME Minutes	PER CENT VOLUME Carbon Dioxide								
1 $\frac{1}{4}$1618
1 $\frac{1}{2}$1318
1 $\frac{1}{4}$1279
3 $\frac{1}{4}$07716
4 $\frac{1}{4}$05142
50464
7 $\frac{1}{4}$0351"

b. See Experiment 48 for another test for carbon dioxide.

191. FOOD AND NUTRITION

We learned, in connection with plants, that food was necessary to promote growth, and to supply the wastes which are going on all the time. With animals, food is even more necessary, for, on account of their great activity, they require it in much larger quantities.

Food serves three purposes: to supply energy, fat, and muscle-forming materials. The warmth of the body is produced by slow oxidation of the carbohydrates contained in some foods, as well as by fats. Fats, in the body, serve as storehouses of food which can be utilized if the food supply is lacking. Proteids supply material for the production of new cells. Other things being equal, the moderately fat person has a better chance to survive a period of starvation than a thin person.

The amount of food consumed does not determine whether a person is to receive great or little good from it. The digestion and assimilation of the food are what count. Many thin persons have enormous appetites, while some fat persons eat but little.

References :—

1. 1304 : 370-371. Food Supply.
2. 1501 : 131-134. Quantity of Food Required.
3. 1503 : 20-22. Foods.
4. 1503 : 317-324. Foods.
5. 1702 : 374-392. Rational Feeding of Men.
6. 1710 : 117-125. Use of Foods.
7. Farmers' Bulletin No. 142. Principles of Nutrition and Nutritive Value of Food.
 - a. 1505 : 91-93. The Four Kinds of Nutrients.
 - b. 1506 : 35-45. Food and its Uses.
 - c. 1507 : 37-61. Foods and Food Habit.
 - d. 1509 : 65-72. Selection and Preparation of Foods.
 - e. 1510 : 51. The Five Food Substances.
 - f. 1511 : 143-192. Nutrition.
 - g. 1708 : 410-411. Food of Man.

192. DIGESTION

When we eat food, it may or may not do us good, according to our ability to digest and to absorb the useful parts of it. Digestion and absorption are entirely different. Absorption is the taking up, by the blood, from the walls of the stomach and intestines, the food material which can be used by the system. Digestion is merely the rendering soluble of the entire mass of food which is taken into the stomach; that is, the food must be turned into a more or less liquid condition.

The stomach supplies the *gastric juice*, which is composed chiefly of an acid called *hydrochloric*, and two ferments called

pepsin and *renin*. The latter acts by coagulating milk; the former softens proteids and tends to change them into a kind of fluid called *peptone*.

The action of the dilute hydrochloric acid is to neutralize the alkali which is always found in food, and to kill bacteria which would cause fermentation. The acid can also begin the changing of proteids, while pepsin cannot act except in the presence of hydrochloric acid. After digestion in the stomach the food is in a liquid form called *chyme*. Starches and sugars are digested in the intestines, and it is here that most of the absorption of food takes place.

References: —

1. 1501 : 51-63. Digestion of Food in the Mouth.
2. 1501 : 66-70. Digestion of Food in the Stomach.
3. 1501 : 79-86. Digestion of Food in the Intestines.
4. 1501 : 89-96. Absorption and Assimilation.
5. 1503 : 330-343. Digestion and Absorption.
6. 1702 : 325-343. Digestion and Nutrition.
 - a. 1505 : 89-116. Food and Digestion.
 - b. 1506 : 76-88. The Digestive System.
 - c. 1507 : 74-87. Digestion of Food; the Mouth and the Throat.
 - d. 1507 : 112-121. The Absorption of Food.
 - e. 1509 : 96-114. Digestion.
 - f. 1510 : 55-58. Digestion.
 - g. 1511 : 193-224. Digestion.

Experiment 84. — Digestion of a Proteid.

Apparatus: Test tubes 6" \times $\frac{3}{4}$ ", beaker 200 c.c., ring stand, asbestos mat, burner, thermometer.

Materials: Pepsin, hydrochloric acid, 10 per cent, cooked white of an egg.

a. Chop finely a small piece of the egg and place it in a test tube with water. Can you see any change after two hours?

b. Put some more chopped egg in another test tube and cover with half water and half 10 per cent hydrochloric acid. This gives a 5 per cent solution. What is the result after two hours?

c. Repeat (a), adding 2 per cent pepsin to the water.

d. Repeat, using 2 per cent pepsin and 5 per cent acid.

e. Put the four tubes (a), (b), (c), and (d) in water maintained at a temperature of 98° F., and note the result in two or three hours.

193. FOOD — VEGETABLE FOOD

The food of man falls naturally into two general divisions: that which is obtained from plants, and that from animals. Since man is an animal, it is doubtful if his body can work to the best advantage without some animal food, either meat, or milk and its products, as well as eggs. Vegetable food is lacking in some of the constituents which form part of the animal body, and those constituents must be supplied.

Vegetable food contains a large amount of water, which is beneficial, while fruits have a very salutary dietetic effect, far exceeding their food value. People, as a rule, do not eat enough vegetables and fruits.

References: —

1. 1407: 514-523. Food Products for Human Use.
2. 1501: 120-129. Vegetable Food.
3. 1702: 397-398. Composition of Vegetable Foods.
4. 1710: 212-222. The Composition and Food Value of Fruits.
5. 1901: 86-99. Bread Raising; Fermented Liquors.
6. Farmers' Bulletin No. 93. Sugar as Food.
7. Farmers' Bulletin No. 105: 19-22. Cereal Breakfast Foods.
8. Farmers' Bulletin No. 112. Bread and Bread Making.
9. Farmers' Bulletin No. 121. Peas, Beans, and Other Legumes as Food.

10. Farmers' Bulletin No. 249. Cereal Breakfast Foods.
11. Farmers' Bulletin No. 256. Preparation of Vegetables for the Table.
12. Farmers' Bulletin No. 293. Use of Fruit as Food.
13. Farmers' Bulletin No. 295. Potatoes and Other Root Crops as Food.
14. Farmers' Bulletin No. 298. Food Value of Corn.
15. Farmers' Bulletin No. 332. Nuts and their Uses as Food.

Experiment 85. — The Amount of Water in Vegetables.

Apparatus: Ring stand, asbestos mat, burner, evaporating dish, balances, set of weights, hard glass tube.

Materials: Potato, apple.

a. Cut the potato or apple into small cubes, and weigh out 20 grams in an evaporating dish. Warm over the burner, at first slowly and then more vigorously, until the material begins to char. Then weigh again. How much water was driven off from the 20 grams? Divide this by twenty and multiply by one hundred and obtain the percentage of water. In 100 pounds of potatoes, how much water is there?

b. Put the dried pieces in a hard glass tube, and heat strongly. When smoke comes from the mouth of the tube, it may be lighted. After all smoke has ceased being evolved, weigh the residue. What is it? See Experiment 18.

194. FOOD—ANIMAL FOOD

While the flesh and some interior organs of animals are used as food for man, and, although some animal food is necessary for man, it is no doubt true that too much meat is eaten. Meat is a decidedly rich and compact food, and man needs but little to supply his wants. Meat is expensive, and thus a proper study of the real necessities for food could cause a person to have better health and to live less expensively.

It does not always follow that the most agreeable food is the best for the system. Some of the cheaper and tougher portions of meat contain more available food than the better and more expensive parts. However, we must remember that a man is not a machine, and that well-being and happiness are just as necessary as the proper food.

References: —

1. 1501 : 107-118. Animal Food.
2. 1605 : 281-282. Importance of Animal Food.
3. 1702 : 393-396. Composition of Animal Foods.
4. 1710 : 228-256. Animal Foods.
5. Farmers' Bulletin No. 34. Meats, Composition and Cooking.
6. Farmers' Bulletin No. 85. Fish as Food.
7. Farmers' Bulletin No. 128. Eggs and their Uses as Food.
8. Farmers' Bulletin No. 182. Poultry as Food.
9. Farmers' Bulletin No. 183. Meat on the Farm.
10. Farmers' Bulletin No. 363. The Use of Milk as Food.
11. Office of Experiment Stations, Bulletin No. 162. The Influence of Cooking upon the Nutritive Value of Meat.
12. Bureau of Animal Industry, Circular 56. Facts concerning the History, etc., of Butter.

195. FOOD ANALYSIS

Under the heading of food analysis are two branches : the tests for the ingredients of which the food is composed, that is, fats, proteids, and carbohydrates ; and the tests for adulterants and preservatives.

The common nutrients are the fats, proteids, and carbohydrates. Starch and sugar are examples of the last. These three kinds of material exist together in many of our foods, although any one of them may be practically alone in some foods. It is of value to us to know what our food contains, in

order that we may consume a sufficient quantity of the right kinds.

There is always a temptation to adulterate food offered for sale, as well as to color it artificially, and also to add preservatives which may affect the health of the consumer. Nearly all of the foreign matter can be detected by the proper test, and the tests for the common substances are given in Experiment 87.

References: —

1. 1501 : 111-112. Adulteration of Milk.
2. 1503 : 21-22. Tests for Nutrients.
3. 1503 : 323-324. Adulterations in Food.
4. 1605 : 282-287. Compositions of Food — the Use of Each Part.
5. 1710 : 123-125. Kinds of Foods.
6. 1710 : 242-250. Milk Analysis and Tests.
7. 1710 : 304-307. Tests for Preservatives and Coloring Matter in Foods.
8. Farmers' Bulletin No. 131. Tests on Butter.
9. Office of Experiment Stations, Bulletin No. 162. Studies on Meat.
 - a. 1505 : 93-94. Adulteration of Food.
 - b. 1506 : 42-43. Adulteration of Food.
 - c. 1507 : 46-48. Composition of Common Foods.
 - d. 1509 : 83-86. Tests on Food.

Experiment 86. — Composition of Food.

Apparatus: Ring stand, burner, asbestos mat, evaporating dish, test tubes, beaker, 100 c.c., flask 150 c.c., funnel, filter paper.

Materials: Iodine solution (make a 10 per cent solution of potassium iodide, dissolve as much iodine in it as possible, and then dilute with nine times as much water). Fehling's solution (make three stock solutions: (1) copper sulphate,

9 g. in 25 c.c. water; (2) sodium hydrate, 30 g. in 250 c.c. water; (3) Rochelle salts, 43 g. in 250 c.c. water. To use, take equal parts of (1), (2), and (3), and two parts water), litmus paper, concentrated nitric acid, ammonium hydrate, benzine or ether, powdered chalk, potato, concentrated sulphuric acid, cotton cloth for strainer.

a. Grind or slice material to be tested, and let stand in a little water. Add a few drops of iodine solution. A blue color indicates starch. If the mixture turns black, add more water and the blue color will appear.

b. Bring from home a little of rice, wheat, beans, peanuts, and apple, and test each for starch.

c. Make some potato pulp, mix it with water, and strain it through a cloth. Let liquid stand until the solid settles, then pour off clear liquid and dry the residue by gentle heat. This is starch. Prove it by testing a little. Also taste a little and describe its taste. Add 1 c.c. concentrated sulphuric acid to 75 c.c. water, and put in it some of your starch. Boil gently for twenty minutes, add powdered chalk until the litmus test indicates no acid, and boil for five minutes more. Filter and boil in the evaporating dish to a thick sirup. Take care not to burn it. Taste some. Conclusions? Test some for starch. What has happened? Save the rest for (*d*).

d. Place some of the material in a little water, and warm to dissolve any sugar which may be present. Add a drop or two of sulphuric acid and some Fehling's solution. If, upon boiling, the blue color changes gradually to red, grape sugar is present. If test is not decisive, add more Fehling's solution and continue to boil. In this way test the material from (*c*) and also the materials brought from home.

e. Cut the material into small pieces, and pour benzine or ether on them. After a few minutes filter, and let the solvent

evaporate in a clean dish; the oil which remains came from the material tested. In this way test other substances.

f. Place the material to be tested in a test tube, and pour over it concentrated nitric acid. A yellow color indicates a proteid. Wash the substance and add a little ammonium hydrate. A dark orange is a sure test for a proteid. Another test is to burn a little of the material. The odor of burning feathers indicates the presence of a proteid.

Experiment 87. — Food Preservatives and Colors.

Apparatus: Ring stand, burner, asbestos mat, evaporating dish, funnel, pipette.

Materials: Concentrated sulphuric acid, ether, gasoline, ferric chloride solution, 1 per cent, formaldehyde test solution (add 1 c.c. of 10 per cent ferric chloride solution to 1000 c.c. concentrated hydrochloric acid), barium chloride solution, 10 per cent, chloroform, bromine water, filter paper, turmeric paper, litmus paper, baking soda, concentrated nitric acid, concentrated hydrochloric acid, ammonium hydrate.

a. Test for copper: Place substance in evaporating dish and burn it with strong sulphuric acid and heat. Add nitric acid, a little at a time, until all carbon is removed. Add a little hydrochloric acid to ash, filter, and add ammonium hydrate. A blue color indicates copper.

b. Test for anatto: Make the sample of milk slightly alkaline with baking soda, and let a piece of filter paper remain in it for a day. If the paper is stained a reddish yellow, there is anatto present. Anatto is harmless, but it is put into milk with intention to deceive.

c. Test for formaldehyde: Add formaldehyde test solution to the material, and warm nearly to boiling. A violet color indicates formaldehyde.

The amount of food consumed does not determine whether a person is to receive great or little good from it. The digestion and assimilation of the food are what count. Many thin persons have enormous appetites, while some fat persons eat but little.

References :—

1. 1304 : 370-371.	Food Supply.
2. 1501 : 131-134.	Quantity of Food Required.
3. 1503 : 20-22.	Foods.
4. 1503 : 317-324.	Foods.
5. 1702 : 374-392.	Rational Feeding of Men.
6. 1710 : 117-125.	Use of Foods.
7. Farmers' Bulletin No. 142.	Principles of Nutrition and Nutritive Value of Food.
a. 1505 : 91-93.	The Four Kinds of Nutrients.
b. 1506 : 35-45.	Food and its Uses.
c. 1507 : 37-61.	Foods and Food Habit.
d. 1509 : 65-72.	Selection and Preparation of Foods.
e. 1510 : 51.	The Five Food Substances.
f. 1511 : 143-192.	Nutrition.
g. 1708 : 410-411.	Food of Man.

192. DIGESTION

When we eat food, it may or may not do us good, according to our ability to digest and to absorb the useful parts of it. Digestion and absorption are entirely different. Absorption is the taking up, by the blood, from the walls of the stomach and intestines, the food material which can be used by the system. Digestion is merely the rendering soluble of the entire mass of food which is taken into the stomach; that is, the food must be turned into a more or less liquid condition.

The stomach supplies the *gastric juice*, which is composed chiefly of an acid called *hydrochloric*, and two ferments called

pepsin and *renin*. The latter acts by coagulating milk; the former softens proteids and tends to change them into a kind of fluid called *peptone*.

The action of the dilute hydrochloric acid is to neutralize the alkali which is always found in food, and to kill bacteria which would cause fermentation. The acid can also begin the changing of proteids, while pepsin cannot act except in the presence of hydrochloric acid. After digestion in the stomach the food is in a liquid form called *chyme*. Starches and sugars are digested in the intestines, and it is here that most of the absorption of food takes place.

References: —

1. 1501: 51-63. Digestion of Food in the Mouth.
2. 1501: 66-70. Digestion of Food in the Stomach.
3. 1501: 79-86. Digestion of Food in the Intestines.
4. 1501: 89-96. Absorption and Assimilation.
5. 1503: 330-343. Digestion and Absorption.
6. 1702: 325-343. Digestion and Nutrition.
 - a. 1505: 89-116. Food and Digestion.
 - b. 1506: 76-88. The Digestive System.
 - c. 1507: 74-87. Digestion of Food; the Mouth and the Throat.
 - d. 1507: 112-121. The Absorption of Food.
 - e. 1509: 96-114. Digestion.
 - f. 1510: 55-58. Digestion.
 - g. 1511: 193-224. Digestion.

Experiment 84. — Digestion of a Proteid.

Apparatus: Test tubes 6" \times $\frac{3}{4}$ ", beaker 200 c.c., ring stand, asbestos mat, burner, thermometer.

Materials: Pepsin, hydrochloric acid, 10 per cent, cooked white of an egg.

a. Chop finely a small piece of the egg and place it in a test tube with water. Can you see any change after two hours?

- b.* Put some more chopped egg in another test tube and cover with half water and half 10 per cent hydrochloric acid. This gives a 5 per cent solution. What is the result after two hours?
- c.* Repeat (*a*), adding 2 per cent pepsin to the water.
- d.* Repeat, using 2 per cent pepsin and 5 per cent acid.
- e.* Put the four tubes (*a*), (*b*), (*c*), and (*d*) in water maintained at a temperature of 98° F., and note the result in two or three hours.

193. Food — VEGETABLE FOOD

The food of man falls naturally into two general divisions: that which is obtained from plants, and that from animals. Since man is an animal, it is doubtful if his body can work to the best advantage without some animal food, either meat, or milk and its products, as well as eggs. Vegetable food is lacking in some of the constituents which form part of the animal body, and those constituents must be supplied.

Vegetable food contains a large amount of water, which is beneficial, while fruits have a very salutary dietetic effect, far exceeding their food value. People, as a rule, do not eat enough vegetables and fruits.

References: —

1. 1407 : 514-523. Food Products for Human Use.
2. 1501 : 120-129. Vegetable Food.
3. 1702 : 397-398. Composition of Vegetable Foods.
4. 1710 : 212-222. The Composition and Food Value of Fruits.
5. 1901 : 86-99. Bread Raising; Fermented Liquors.
6. Farmers' Bulletin No. 93. Sugar as Food.
7. Farmers' Bulletin No. 105 : 19-22. Cereal Breakfast Foods.
8. Farmers' Bulletin No. 112. Bread and Bread Making.
9. Farmers' Bulletin No. 121. Peas, Beans, and Other Legumes as Food.

10. Farmers' Bulletin No. 249. Cereal Breakfast Foods.
11. Farmers' Bulletin No. 256. Preparation of Vegetables for the Table.
12. Farmers' Bulletin No. 293. Use of Fruit as Food.
13. Farmers' Bulletin No. 295. Potatoes and Other Root Crops as Food.
14. Farmers' Bulletin No. 298. Food Value of Corn.
15. Farmers' Bulletin No. 332. Nuts and their Uses as Food.

Experiment 85. — The Amount of Water in Vegetables.

Apparatus: Ring stand, asbestos mat, burner, evaporating dish, balances, set of weights, hard glass tube.

Materials: Potato, apple.

a. Cut the potato or apple into small cubes, and weigh out 20 grams in an evaporating dish. Warm over the burner, at first slowly and then more vigorously, until the material begins to char. Then weigh again. How much water was driven off from the 20 grams? Divide this by twenty and multiply by one hundred and obtain the percentage of water. In 100 pounds of potatoes, how much water is there?

b. Put the dried pieces in a hard glass tube, and heat strongly. When smoke comes from the mouth of the tube, it may be lighted. After all smoke has ceased being evolved, weigh the residue. What is it? See Experiment 18.

194. Food — ANIMAL Food

While the flesh and some interior organs of animals are used as food for man, and, although some animal food is necessary for man, it is no doubt true that too much meat is eaten. Meat is a decidedly rich and compact food, and man needs but little to supply his wants. Meat is expensive, and thus a proper study of the real necessities for food could cause a person to have better health and to live less expensively.

It does not always follow that the most agreeable food is the best for the system. Some of the cheaper and tougher portions of meat contain more available food than the better and more expensive parts. However, we must remember that a man is not a machine, and that well-being and happiness are just as necessary as the proper food.

References: —

1. 1501 : 107-118. Animal Food.
2. 1605 : 281-282. Importance of Animal Food.
3. 1702 : 393-396. Composition of Animal Foods.
4. 1710 : 228-256. Animal Foods.
5. Farmers' Bulletin No. 34. Meats, Composition and Cooking.
6. Farmers' Bulletin No. 85. Fish as Food.
7. Farmers' Bulletin No. 128. Eggs and their Uses as Food.
8. Farmers' Bulletin No. 182. Poultry as Food.
9. Farmers' Bulletin No. 183. Meat on the Farm.
10. Farmers' Bulletin No. 363. The Use of Milk as Food.
11. Office of Experiment Stations, Bulletin No. 162. The Influence of Cooking upon the Nutritive Value of Meat.
12. Bureau of Animal Industry, Circular 56. Facts concerning the History, etc., of Butter.

195. FOOD ANALYSIS

Under the heading of food analysis are two branches : the tests for the ingredients of which the food is composed, that is, fats, proteids, and carbohydrates ; and the tests for adulterants and preservatives.

The common nutrients are the fats, proteids, and carbohydrates. Starch and sugar are examples of the last. These three kinds of material exist together in many of our foods, although any one of them may be practically alone in some cases. It is of value to us to know what our food contains, in

order that we may consume a sufficient quantity of the right kinds.

There is always a temptation to adulterate food offered for sale, as well as to color it artificially, and also to add preservatives which may affect the health of the consumer. Nearly all of the foreign matter can be detected by the proper test, and the tests for the common substances are given in Experiment 87.

References: —

1. 1501 : 111-112. Adulteration of Milk.
2. 1503 : 21-22. Tests for Nutrients.
3. 1503 : 323-324. Adulterations in Food.
4. 1605 : 282-287. Compositions of Food — the Use of Each Part.
5. 1710 : 123-125. Kinds of Foods.
6. 1710 : 242-250. Milk Analysis and Tests.
7. 1710 : 304-307. Tests for Preservatives and Coloring Matter in Foods.
8. Farmers' Bulletin No. 131. Tests on Butter.
9. Office of Experiment Stations, Bulletin No. 162. Studies on Meat.
 - a. 1505 : 93-94. Adulteration of Food.
 - b. 1506 : 42-43. Adulteration of Food.
 - c. 1507 : 46-48. Composition of Common Foods.
 - d. 1509 : 83-86. Tests on Food.

Experiment 86. — Composition of Food.

Apparatus: Ring stand, burner, asbestos mat, evaporating dish, test tubes, beaker, 100 c.c., flask 150 c.c., funnel, filter paper.

Materials: Iodine solution (make a 10 per cent solution of potassium iodide, dissolve as much iodine in it as possible, and then dilute with nine times as much water). Fehling's solution (make three stock solutions: (1) copper sulphate,

9 g. in 25 c.c. water; (2) sodium hydrate, 30 g. in 250 c.c. water; (3) Rochelle salts, 43 g. in 250 c.c. water. To use, take equal parts of (1), (2), and (3), and two parts water, litmus paper, concentrated nitric acid, ammonium hydrate, benzine or ether, powdered chalk, potato, concentrated sulphuric acid, cotton cloth for strainer.

a. Grind or slice material to be tested, and let stand in a little water. Add a few drops of iodine solution. A blue color indicates starch. If the mixture turns black, add more water and the blue color will appear.

b. Bring from home a little of rice, wheat, beans, peanuts, and apple, and test each for starch.

c. Make some potato pulp, mix it with water, and strain it through a cloth. Let liquid stand until the solid settles, then pour off clear liquid and dry the residue by gentle heat. This is starch. Prove it by testing a little. Also taste a little and describe its taste. Add 1 c.c. concentrated sulphuric acid to 75 c.c. water, and put in it some of your starch. Boil gently for twenty minutes, add powdered chalk until the litmus test indicates no acid, and boil for five minutes more. Filter and boil in the evaporating dish to a thick sirup. Take care not to burn it. Taste some. Conclusions? Test some for starch. What has happened? Save the rest for (*d*).

d. Place some of the material in a little water, and warm to dissolve any sugar which may be present. Add a drop or two of sulphuric acid and some Fehling's solution. If, upon boiling, the blue color changes gradually to red, grape sugar is present. If test is not decisive, add more Fehling's solution and continue to boil. In this way test the material from (*c*) and also the materials brought from home.

e. Cut the material into small pieces, and pour benzine or ether on them. After a few minutes filter, and let the solvent

evaporate in a clean dish; the oil which remains came from the material tested. In this way test other substances.

f. Place the material to be tested in a test tube, and pour over it concentrated nitric acid. A yellow color indicates a proteid. Wash the substance and add a little ammonium hydrate. A dark orange is a sure test for a proteid. Another test is to burn a little of the material. The odor of burning feathers indicates the presence of a proteid.

Experiment 87. — Food Preservatives and Colors.

Apparatus: Ring stand, burner, asbestos mat, evaporating dish, funnel, pipette.

Materials: Concentrated sulphuric acid, ether, gasoline, ferric chloride solution, 1 per cent, formaldehyde test solution (add 1 c.c. of 10 per cent ferric chloride solution to 1000 c.c. concentrated hydrochloric acid), barium chloride solution, 10 per cent, chloroform, bromine water, filter paper, turmeric paper, litmus paper, baking soda, concentrated nitric acid, concentrated hydrochloric acid, ammonium hydrate.

a. Test for copper: Place substance in evaporating dish and burn it with strong sulphuric acid and heat. Add nitric acid, a little at a time, until all carbon is removed. Add a little hydrochloric acid to ash, filter, and add ammonium hydrate. A blue color indicates copper.

b. Test for anatto: Make the sample of milk slightly alkaline with baking soda, and let a piece of filter paper remain in it for a day. If the paper is stained a reddish yellow, there is anatto present. Anatto is harmless, but it is put into milk with intention to deceive.

c. Test for formaldehyde: Add formaldehyde test solution to the material, and warm nearly to boiling. A violet color indicates formaldehyde.

d. Test for borates or boric acid: Treat as in *(a)* without the addition of ammonium hydrate. If turmeric paper is wet with mixture and turns red upon drying, there is boric acid, or some borate, present.

e. Test for sulphites or sulphurous acid: odor, that of burning matches. Add little bromine water, and warm. Then add barium chloride solution. White precipitate indicates that there had been some sulphite present.

f. Test for benzoates or benzoic acid: Add one tenth volume of chloroform and a few drops of sulphuric acid. Do not shake. When chloroform has separated, remove it with a pipette and allow it to evaporate. Crystal plates are formed, and they give off pungent odor when heated.

196. WATER ANALYSIS

There are a few simple tests which may be applied to water, and thereby prevent sickness from the use of impure water. It does not follow that clear and sparkling water is pure, nor that muddy water is bad. Chemical tests are the only ones upon which complete dependence may be placed. Even the sense of smell, or that of taste, may pronounce the water bad when the very material which causes the disagreeable effect is beneficial. Naturally, however, pure water contains nothing but air, and our senses do detect some kinds of foreign matter, but not all kinds. Poison from bacterial action cannot be detected, but if the organic material is plentiful in the water, bacterial poisons should be suspected.

There may be considerable quantities of solid material dissolved in water and the water still be harmless. Thus no harmful effect has been noticed where hard water has been used for drinking purposes.

References:—

1. 1501 : 135-139.	Drinking Water.
2. 1503 : 325.	Impure Water.
3. 1702 : 59-61.	Impurities in Water.
4. 1703 : 43-45.	Water and its Impurities.
5. 1710 : 64-78.	Tests for the Impurities in Water.
a. 1706 : 474-475.	Simple Tests for Impurities in Water.

Experiment 88.— Water Analysis.

Apparatus: Ring stand, burner, asbestos mat, evaporating dish, several test tubes.

Materials: Potassium permanganate solution, 10 per cent, silver nitrate solution, 5 per cent, nitric acid, 1-4, concentrated sulphuric acid, alcoholic solution of castile soap, common salt, distilled water.

a. Boil to dryness the evaporating dish full of water. The residue is the total solid matter contained in the water. Heat strongly the dried material. If it chars, there is organic matter in the water. Prove it by (b).

b. Fill one test tube half full of distilled water and another test tube half full of faucet water. To the latter add a bit of paper, and to both a few drops of concentrated sulphuric acid. Now add enough potassium permanganate solution to color each liquid the same tint of light purple. Heat the tube, containing the paper, just to the boiling point, and note the change. Then heat the other tube. Is there any change? To test a sample of water for vegetable material, add a little potassium permanganate and a few drops of concentrated sulphuric acid, and heat to boiling. Bring a sample of water from home, or from some puddle, and test it.

c. Add a little salt to a test tube half full of water, put in a few drops of nitric acid, and then add a few drops of silver nitrate. The result is silver chloride. Describe it. This

is the test for chloride, and water which gives this result with nitric acid and silver nitrate may contain animal matter. Bring a sample of water and test it. Always add the nitric acid first.

d. Hardness can be indicated by seeing how much soap is necessary to produce a strong lather. To half a test tube of distilled water, add a very little soap solution, cover the open end with the thumb, and shake. See if the lather will last three minutes. If not, add a little more soap solution. Now test a sample of water and see how much more soap is needed to produce the same result. Why is hard water said to be expensive to use?

197. FOOD — PRESERVATION OF FOOD

Bacteria and molds, as well as other microorganisms, live upon the same food as do man and the other animals. For that reason we must prevent these undesirable organisms from entering our food. This can be accomplished by heating, drying, salting, and smoking the material to be preserved; and, in some cases, a large proportion of sugar will prevent the unfavorable growths. It may be necessary to inclose the food in a bacteria- and mold-proof container.

Coolness and cleanliness will prevent the unnecessary introduction and rapid growth of bacteria. Eggs may be preserved by immersing them in a 10 per cent solution of water glass.

References: —

1. 1710 : 297-307. Preservation of Food.
2. 1901 : 139-156. Preservation of Food.
3. 1901 : 157-168. Use of Preservatives.
4. 1901 : 169-181. Preservation by Canning.

5. Farmers' Bulletin No. 122:29-31. Preparation of Unfermented Grape Juice.
6. Farmers' Bulletin No. 175. Home Manufacture and Use of Unfermented Grape Juice.
7. Farmers' Bulletin No. 203. Canned Fruits, Preserves, and Jellies.
8. Farmers' Bulletin No. 359. Canning Vegetables in the Home.
9. Farmers' Bulletin No. 375. Care of Food in the Home.
10. Farmers' Bulletin No. 413. The Care of Milk and its Use in the Home.
 - a. 1506:46-53. Microbes and Molds.
 - b. 1902:236-250. Preservation of Food.
 - c. 1903:42-43. Salts and Sugar as Preserving Agents.
 - d. 1904:153. The Care of Foods.

198. THE MIND

The distinguishing feature which differentiates man from other animals is his mind. The more he uses his mind, along the right direction, the less an animal he becomes. Nevertheless, since the brain is the organ of the mind, and since the brain is a physical organ, the mind is necessarily affected by changes in the body.

If the organs of digestion are not performing their work properly, the brain is temporarily affected and the person becomes irritable. It is quite a question as to the true responsibility for his ill-nature, under these conditions. The old saying that "the way to reach a man's heart is through his stomach," contains as much physiological truth as it does common sense. Unless the body is normal, the mind cannot act as it would under more favorable circumstances.

It must be remembered, however, that the mind can exert an influence over the body, controlling it and refining it, through education, to the highest ideals of mankind.

References: —

1. 1501: 305-320. Influences which Affect the Mind.
2. 1503: 400-418. The Nervous System.
 - a. 1505: 117-141. The Nervous System.
 - b. 1506: 215-244. The Nervous System and the Senses.
 - c. 1507: 321-327. Care of the Brain; Disease of Nervous System.
- d. 1507: 328-339. A Clear Mind the Need of the Day.
- e. 1509: 241-245. Use and Care of the Nervous System.
- f. 1511: 252-253. The Mind.

199. THE SENSES — SIGHT

Most animals have five senses: sight, hearing, smell, taste, and feeling. These senses are all for use; if they are not used, they become weakened, and certain senses may be lost entirely. Thus fish in underground waters, not needing to see, have no eyes. The ability to see and to hear enables animals to guard against the approach of enemies, as well as to help them secure their own food. With the lower animals the sense of smell aids in a similar way.

With man, in the civilized state, the use of the senses, especially those of smell and hearing, is not so apparent. All our senses are to protect us, or help us, and we should not neglect their warnings. Pain signifies that there is some local trouble. We should try to correct the trouble, and the pain will pass away, since there is no longer any need of a warning. To stop the pain by paralyzing the nerves, without curing the ailment, is to take away from the body its protection. A bad odor or a bad taste signifies that there are decay, bacteria, and possibly disease in the material producing the odor or taste. The warnings of the senses must be heeded.

The sense of sight is the one which, without doubt, gives us

the most pleasure and the greatest feeling of security. The eye is by far the most sensitive sense organ.

References: —

1. 1501 : 323-325. Taste and Smell.
2. 1501 : 333-344. The Eye.
3. 1503 : 419-427. The Senses.
4. 1803 : 435-437. The Eye — Vision.
 - a. 1505 : 142-157. The Senses.
 - b. 1506 : 237-242. The Sense Organs.
 - c. 1506 : 246-249. The Eye.
 - d. 1507 : 340-361. The Eye and Light.
 - e. 1509 : 246-275. The Special Senses.
 - f. 1510 : 114-116. The Value of the Nerves. — Sense Organs.
 - g. 1511 : 314-366. The Special Senses.
 - h. 1806 : 152-154. The Eye. Color Sensation.

Experiment 89. — Persistence of Vision. — Fatigue.

Apparatus: Piece of cardboard 2" × 2", string, colored cards — red, bluish green, yellow, blue, purple.

a. Punch a hole in each of two opposite ends of the cardboard, and in each tie a string in a loop about eight inches long. Draw the head of a man on one side and some parallel lines (to represent prison bars) on the other side. To "put the man in prison" cause the piece of cardboard to revolve rapidly by putting the loops over your two thumbs and turning the cardboard until it winds up the string in spirals, then gently pull the hands apart. The impression which the eye receives from one side of the cardboard lasts until the other side is seen. Therefore both *seem* to be seen simultaneously. This will explain the moving pictures wherein a series of pictures are thrown on a screen with less than a tenth of a second between successive ones. The impression from one lasts until another is seen.

b. Look steadily for one minute at the red card, and then immediately look at a white paper or wall. What color do you see? You will remember that white is composed of all the other colors. Now the eye is tired from seeing one color, and responds to the other colors contained in the white. The blending of these other colors is what produces the apparent color. Repeat with the other cards, and tabulate your results. The color which appears to be present on the white is called the complementary color of the original color.

200. SOUND AND HEARING

Sound is caused by some material body moving to and fro, that is, vibrating at least sixteen times a second. Impulses are sent out which are conveyed by the air. There must be some material medium, or sound will not be carried from its source. Liquids carry sound better than gases, and solids better than liquids. In each case, however, the sound must originate in the medium which is to convey it. We receive the sensation, which we call *sound*, due to the beating of the vibrations of the air upon the eardrums, which, in turn, convey the vibrations within, to the nerves. Vibrations coming at regular intervals are musical sounds; other vibrations cause merely noise.

As we understand it, sound is the sensation, and, while the vibrations would exist even if there were no ears to hear, yet sound does not exist outside of the nervous system. In this respect, sound and light are similar,—both are sensations.

References: —

1. 1501 : 325-330. The Ear and Hearing.
2. 1501 : 349-353. The Voice.
3. 1503 : 421-422. The Organ of Hearing.

4. 1803 : 343-344. Sources of Sound.
5. 1803 : 351-352. Musical Sounds and Noises.
 - a. 1506 : 241-244. The Sense of Hearing — the Ear.
 - b. 1507 : 362-373. The Ear and Sound.
 - c. 1509 : 252-256. Hearing and Sound.
 - d. 1801 : 140-152. Sound ; its Transmission and Velocity.
 - e. 1804 : 186-197. Origin of Sound and its Transmission.
 - f. 1805 : 169-180. Waves — Sounds ; its Transmission.
 - g. 1805 : 192-195. Characteristics of Sound.
 - h. 1806 : 441-444. Sound ; its Sources and Transmission.
 - i. 1808 : 163-165. The Nature of Sound.
 - j. 1808 : 180. Properties of Musical Tones.

Experiment 90. — The Origin of Sound. — Music.

Apparatus: A vise or clamp, piece of clock spring, pins, hammer, piece of wood.

a. Fasten the piece of clock spring in the vise so that a six-inch section of it is free to move. Cause it to vibrate. Does it produce a musical tone? Shorten the free end of the spring, and vibrate again. What is the result? Continue to shorten the spring. What happens, and what is the final result? What is the origin of sound?

b. Drive a pin into a piece of wood, and make it vibrate. Note the tone. Now drive another pin a little deeper into the wood, trying to cause the pin to give forth the next higher note in the ordinary musical scale. In this manner drive six more pins, completing the scale.

c. After the practice in (b) try driving in a row of pins which will play some simple air when they are caused to vibrate in succession.

Experiment 91. — The Megaphone and Mechanical Telephone.

Apparatus: Two tin vegetable cans, or baking powder tins, string, brass rivets for paper, scissors.

Materials: Sheet of bristol board, 22" \times 28".

a. To make a megaphone: Tie a string two feet long to a pencil, and with a radius of twenty-two inches, using one corner of the bristol board as a center, draw as long an arc as possible on the paper. With the same point as a center, and with a radius of four inches, describe another arc. Cut the bristol board along the lines. Now roll up the bristol board to form a funnel, and fasten every five or six inches, along the edge, with the paper rivets.

b. Send your partner a hundred feet away, and speak to him in an ordinary tone of voice. He will probably not hear you. Now place the small end of your megaphone to your lips. direct the large end toward your partner, and speak to him in the same tone of voice. Does he hear you? Have your partner speak to you in the same manner. Go so far away from your partner that you can just carry on a conversation by means of the megaphone. Does the megaphone help? The megaphone prevents the vibrations of the voice from spreading, and guides them in the desired direction.

c. Punch a hole in the center of the bottom of the cans, with a nail. Push a string through the hole in each, and tie a knot in it to keep it from slipping through again. The cans should be separated by a string at least one hundred feet long. Hold the can to your mouth and have your partner hold his can to his ear. Try whispering to him. Have him repeat your actions. The string must be held taut, for it carries the vibrations, and the more characteristics of a solid which it has, the better will the vibrations be carried.

A telephone like this may be used for a distance of one mile. Very satisfactory results may be obtained by the following method: At each end of the line a board, one foot wide, should be fitted in a window. In the board should be

cut a hole so that a large-sized lard pail will just fit it. Fasten the pail so that it will project outside, with its open end inside. To do this, drive several nails radically from the inside edge of the pail, through it into the board. A small hole should be punched in the exact center of the bottom of the pail, to receive a wire, No. 20, galvanized iron. The end of the wire should be passed through a washer and fastened. The wire must be supported, if it is longer than two hundred feet, by loops of tarred cord, at least six inches long. This allows free movement of the wire. For this reason the wire should not touch anything except the tarred cord. To call your party, knock on the bottom of the pail. The noise will be about equal at both ends of the line.

201. MAN'S PLACE IN NATURE

Information concerning man may be obtained from geology, biology, and history. The last-named, so far as the records show, tells us only of the last few thousands of years. Geological records, left in the enduring rock, as it is sometimes called, indicate that man lived almost countless thousands of years before any other records were made. In addition, it must be remembered that rock itself disintegrates and may be changed into other kinds of rocks. Therefore, it is very probable that man existed long before the time which is indicated by any of the geological records.

Biology, in its study of life from the single-celled amoeba up through all forms and aggregations of cells; in its classifications of all animal life by structure and by habits, has placed man far above all other animals among the vertebrate mammals called the *primates*. See Section 183, Animal Life — Man.

While man, due to his intelligence, may rise superior to circumstances and environment, yet he is entirely dependent upon nature. All possible mental attainments cannot free man from the necessity of supplying his animal needs. He requires air to breathe, water to drink, and food to eat. He suffers pain and discomfort as does any other animal, and must pay the penalty of wrong living as any animal must. Nevertheless, above and beyond all this, man's mind, through education of mind and body, may rise superior and cause him to merit truly the title of "Lord of Creation."

References: —

1. 1205 : 414. *Man a Primate.*
2. 1304 : 369-375. *Man and Nature.*
3. 1503 : 316. *Man's Place in Nature.*
 - a. 1302 : 383-384. *The Ascent of Man.*
 - b. 1303 : 345-346. *Races of Mankind.*
 - c. 1305 : 350-358. *Man.*
 - d. 1307 : 334-335. *Man.*

202. NATURE AND BUSINESS

The natural conditions in which man finds himself have a great effect upon the kind of business which he will pursue, and his character in some special direction. This is especially true of uncivilized man, for nature is his master. As knowledge and inventiveness increase, man gains a mastery over nature and alters many of those conditions which are unsatisfactory to him.

The business of a nation is affected similarly to the life of the individual. Mountains and plains, bays and harbors, all influence business, which follows the paths of least resistance unless great gain is expected. Any desirable feature

which is lacking must be supplied, and so we find nations bridging chasms, burrowing through mountains, building harbors and breakwaters, and joining oceans by canals. Knowledge always rises superior to environment and makes its own conditions.

References: —

1. 1304 : 377-379. Development of Commerce.
2. 1304 : 379-380. Influence of Man on Nature.
 - a. 1302 : 391-392. The Development of Natural Resources.
 - b. 1303 : 364-367. Geographical Factors in the Life of Civilized Peoples.
 - c. 1305 : 365. Causes of Civilization.
 - d. 1307 : 349-351. Man's Relation to Physiography.
 - e. 1308 : 125-142. Man's Relation to Natural Conditions.
 - f. 1308 : 192-211. Nature of Trade Routes and Stations.
 - g. 1311 : 369-370. Man's Influence on Nature.

203. MAN'S APPLICATIONS OF NATURE'S PRINCIPLES

The great inventions and the wonderful machines which man has made are but the application of natural law. Man cannot change the laws of nature, but he can produce conditions which are favorable for the action of those laws, directing and controlling them so that they may accomplish what he desires. Man discovers, and applies the knowledge of his discoveries; he cannot, in the true sense, produce or create. Nature is the great prime mover.

A few of the direct applications of natural law are: heating by condensation, cooling by evaporation and expansion, cleaning by partial vacuum, power from explosions and expansion, transmission of power by water, compressed air, and electricity, the production of electricity and all of its uses. On the

biological side there are the production of new plants by directing their propagation, the control of bacteria, and many medical discoveries.

References: —

- a. 1305: 372. Man's Control over Nature.
- b. 1308: 128-130. Human Adaptation. — "Conquest of Nature."
- c. 1309: 319-321. Man's Influence upon Physical Geography.
- d. 1311: 353-354. Fuel and Light.

204. HOW TO PLAN A HOUSE AND BARN

The heart of a house is its kitchen. This is the room in which the housewife spends more than half of her time, and it should have more thought given to it than to any other part of the house. The beautiful and the artistic should not be neglected, but, if the beautiful objects require extra work, or cause inconvenience, they should be removed or altered. On the other hand, conveniences need not be ugly, and may be beautiful.

The kitchen should be planned first and the rest of the house adapted to the plan of the kitchen. The coldest part of the house, that is, the northern side, or corner, should be reserved for the kitchen. Where possible, the corners of the house should point to the four points of the compass. This will give sunlight in every room, part of each day. In a two-story house, the dining room should be on the eastern corner. Unless a library is desired, the rest of the lower story should be given to one large room. In this case, the bathroom should be as nearly over the kitchen as possible, to save in plumbing. At the same time, it should be between two of the bedrooms,

with doorways from each opening into it, as well as a third doorway opening into the upper hall.

In a one-story building, the kitchen should be on the eastern corner, the living room on the southern corner, and the dining room between. The other side of the house should contain the bedrooms and the bathroom. Each bedroom should have a large closet with a window in it. Closets should not be crowded in, here and there, but the house should be made large enough to contain the space necessary for proper closets.

Instead of having the toilet in the bathroom, it is an excellent plan to have separate rooms with toilet in one of them, and the bathtub and lavatory in the other. The low tank toilet is the best pattern.

Returning now to the kitchen: The sink should be against an inside wall with a window at the left. The bottom of the sink should be at such a height that it can be reached with the extended fingers when its user stands erect. This brings the sink higher than is usual, but is the proper height to prevent an aching back and rounded shoulders. Underneath the sink there may be a shelf, but the space should not be inclosed, as such a closet is liable to be unsanitary.

The stove should be placed as far from the sink as possible, so that a person can wash the dishes without suffering unnecessarily from the heat. This will bring the stove into the diagonally opposite corner, with a window at its right. Cooking utensils should be hung near the stove.

The other inside wall should have cupboards for dishes and the storage of food. In the outside wall, next to a screened porch, if possible, there should be a cold closet and an ice chest, the latter arranged to receive ice from outside. The cold closet should have a bottom air inlet, running from out-

doors and not from under the house, and a top air outlet running up the outside of the house and painted black. This outlet pipe becomes heated and produces a current of cool air through the cold closet. See Section 205, Conveniences for the Home. See references for plans of barns.

References: —

1. 1501: 253. *Choice of a House.*
2. *Farmers' Bulletin No. 126. Practical Suggestions for Farm Buildings.*
3. *Farmers' Bulletin No. 342: 30-32. A Model Kitchen.*
4. *Bureau of Animal Industry, Circular 131. Designs for Dairy Buildings.*
- a. 1507: 386-389. *The Home.*

205. CONVENiences FOR THE HOME

There is perhaps no better example of custom being handed on from generation to generation than is shown in the home. Women are expected to use the same kind of utensils and appliances, as well as to endure the same inconveniences, as their mothers did. Man has improved his workshops and factories, but the business of the house has been neglected until recently. Now there are many conveniences, some of which are inexpensive, while others are quite costly. The expensive ones, however, are long-lived and are cheap in the end, when the great saving of energy and time on the part of the housewife is taken into consideration. Housework is a necessity, but there is no reason why it should approach slavery.

The workshop of the house is the kitchen. This should be made moderately small and have everything convenient in order to save miles of walking. Many things may be done while sitting, and an office stool should be in every kitchen. This may be slid under a shelf when not in use.

Just as a good workman may get along with poor tools, yet cannot work to the best of his ability without good ones, so a housekeeper needs the best that can be obtained in the way of labor-saving appliances and utensils. A few of the conveniences and some of the necessities which may be mentioned are as follows:—

Enamel sink and wooden drying boards on each side; hot and cold water at sink, and cold water faucet made to swing over the stove; faucet attachment to prevent spattering of water; scraper, made of rings, for removing burned material from pots; scraper, made with flat rubber edge, for removing grease from table dishes; strainer at sink, to prevent matter going down the drainpipe; bottle washer which can be used for glass chimneys; polishing cloth for silver; kitchen cooking cabinet, portable or built-in; kitchen table, with bins and drawers, as second choice for kitchen cabinet; billhook for keeping store slips in the order in which they come; card index, made of heavy envelopes, for saving recipes; standard measuring spoons; glass measuring cup; scales; meat grinder; vegetable slicer; potato ricer, for making mashed potatoes or aiding in the reduction of any vegetable to a paste; electric, water-power, or even hand-power, washing machine, where the laundry work is performed at home; electric or alcohol iron; chemical dust rag which picks up the dust; a yacht mop for dusting hardwood floors. Besides these, the housekeeper should have anything else which will make the work easier and save time.

The walls of the kitchen and the bathroom should be covered with hard paint, or washable wall paper, of a light tint. The floors of both rooms should be covered with linoleum.

References: —

1. Farmers' Bulletin No. 270. *Modern Conveniences for the Farm Home.*
2. Farmers' Bulletin No. 317: 5-9. *The Farm Home.*
3. Reprint from Yearbook Department of Agriculture for 1909: *Comforts and Conveniences in Farmers' Homes.*

206. SANITATION

“Sanitation” comes from the same source as the word *sanity*, and the two should go hand in hand. Conditions are now no worse than they were hundreds of years ago, when little was known and less was thought on the subject of sanitation. Now we know the causes of many diseases, and that they owe their origin to unsanitary conditions. For that reason there are some persons who seem to think that the fault lies in knowing too much, and that if we did not recognize the presence of bacteria, they would do no harm. We cannot afford to fail to recognize the true conditions, and we should take steps to remedy the conditions according to our knowledge of sanitation and sanitary measures.

There are bacteria everywhere, in everything. Many are necessary, and even the bacteria of decay, which trouble the housewife, are of great value in the production of soil and the removal of plant and animal waste. On the other hand, disease bacteria are very liable to be present in putrefaction, and we must guard ourselves against their attacks.

Cleanliness and neatness are sanitary measures. In fact, if there were no contamination from the outside, cleanliness would be a sufficient guard against disease. We should not allow the refuse from the kitchen to accumulate even for a few days. The decaying material serves as a place where

flies lay their eggs. The flies carry disease germs into the house and contaminate food. If a neighborhood did not feed the flies, there would be no flies.

The drainage from the toilets, and even from the kitchen sink, should be taken care of in the best possible way. Cess-pools are not very satisfactory under the best conditions, as the seepage may go where it will do harm. The septic tank system, wherein bacteria change the material into substances which are harmless, is the best, where there is no regular system of drainage. See next section.

Personal cleanliness is a part of sanitary living. Bedrooms should be well ventilated and closets for clothes should have windows in them. Sunshine is the greatest germ killer known, and every room should have as much sunshine as possible.

References: —

1. 1702: 361-362. Sanitary Conditions.
2. 1710: 74-78. Drinking Water and Disease.
3. 1901: 151-154. A Sanitary Ice Chest.
4. 1901: 253-254. General Rules of Sanitation.
5. Bureau of Animal Industry, Circular 158. Production of Market Milk.
 - a. 1502: 473-475. Sanitation in School.
 - b. 1505: 23-26. Bathing and Clothing.
 - c. 1505: 162-164. Protection against Disease.
 - d. 1506: 187-189. The Bath. — Clothing and Health.
 - e. 1507: 244-248. Care of the Skin and Clothing.
 - f. 1509: 207-208. Necessity for Cleanliness.
 - g. 1511: 288-297. Care of the Skin. — Bathing.
 - h. 1904: 187-192. Practical Sanitation.
 - i. 1905: 64-72. The Care of the School Building.

207. SANITARY PLUMBING

In the olden times, when people first used pipes to conduct waste water from their houses, they employed straight pipes;

that is, pipes without certain bends, or cavities, which are called *traps*. Under those conditions the gases from the decomposing material rose in the pipes and entered the buildings, producing sickness. The common name for this gas is sewer gas, and it should not be allowed to enter a building under any circumstances.

The first improvement was to bend the pipe into an S-shape, which, turned on its side, produced a U in the pipe. In this bend water was expected to remain, and thus prevent the entrance of the sewer gas. Under favorable conditions, this form of trap operated successfully, but often the sewer gas came up the drainpipe, notwithstanding its shape. It was then discovered that the traps acted as siphons and were entirely emptied by the outgoing stream. To prevent the siphon effect, a vent pipe was connected to the top of the bend, and this pipe was run up through the roof of the building. Not only is the trap thus prevented from emptying, but any accumulation of sewer gas is led off from the pipes without harm to the dwellers in the building.

Every drain should have a trap, and every trap should have a vent pipe, running up through the roof. There is a dangerous habit of using one trap for two or more near-by drains, and it should be discouraged. On the other hand, one vent pipe can be safely used for many traps.

There should be a large trap in the main drain where it leaves the building. This trap may be what is called *drum trap*, and need not be ventilated. All traps should have a tightly fitting cover, which can be removed for purposes of cleaning out any solid material which has accumulated.

Cesspools should be vented, and the vent pipe should run up high enough to prevent any annoyance from the gases.

It must be remembered, however, that even sanitary plumb-

ing may become unsanitary through carelessness. Grease will gradually stop up the sink drain if hot water is not poured down it occasionally, while the toilet drain may be blocked by paper or rubbish. It is a good plan not to throw anything into the toilet. If the drains do become stopped, the traps should be opened and cleaned out. Wire No. 10 may then be used to force or pull out most of the accumulated material, and a saturated solution of caustic potash can be poured into the pipes to remove the remaining part.

References: —

1. 1501 : 252-253.	Dangers from Sewage. — Plumbing.
2. 1605 : 392-395.	The Septic Tank.
3. 1901 : 246-248.	Sewage and Plumbing.
a. 1507 : 394-395.	Sewage.
b. 1511 : 137-139.	Cesspools; Sewers and Plumbing.
c. 1902 : 83-84.	The Septic Tank.
d. 1903 : 112-114.	Bacterial Purification of Sewage.
e. 1904 : 193-194.	Building a Dry Closet.
f. 1905 : 60-64.	Sewage Disposal in Schools.

208. SIMPLE HOUSEHOLD REMEDIES

The kitchen closet usually contains, for domestic purposes, enough remedies to cure ordinary ailments. A person should resort to the use of medicines as little as possible, but it is well to know how to cure one's self, as well as to aid others, when need arises.

Table salt and vinegar make a good gargle for sore throat. The vinegar should be diluted with water, if it is unpleasantly acid.

Red pepper and hot water, taken internally, may aid a cold, if taken during its early stages. Drink a great deal of water, exercise, and bathe.

Mustard and hot water may be used for soaking the feet

in order to cure a cold. Likewise mustard plaster, made by mixing flour, mustard, and water and spreading the mass on one cloth and covering with another cloth, may be used to relieve "cold in the chest." In both cases, the mustard acts as an irritant and, to do good, must hurt. It causes the blood to leave the congested locality, which is all that a simple cold is, and thus produces relief.

Cloves and allspice, applied to the gum near an aching tooth, will relieve the pain. Toothache, except neuralgia, is a warning to go to a dentist as soon as possible. If the pain is neuralgic, consult a doctor; do not use any of the "pain-killers" without medical advice.

Baking soda, dissolved in water and taken internally, will relieve sour stomach temporarily. Sour stomach, if chronic, is due to poor digestion. Do not chew gum, even "pepsin gum," to cure indigestion. It causes unnecessary waste of the saliva. Consult a doctor.

Baking soda, dissolved in water and applied to the skin before exposure to poison oak or poison ivy, will prevent unpleasant results due to poisoning. Even after exposure, if applied as soon as possible, it may make the poisoning slight. Mere bathing will not accomplish any good; the poison is an acid and must be neutralized. In very bad cases of exposure, just the hands may be washed in a solution of washing soda and then washed in clear water. Do not use washing soda for the face or any part of the body except the hands. Alcohol may remove the poison.

Cracker soaked in hot milk may be used as a poultice for local inflammations and swellings. Do not neglect any gathering of pus, as it may lead to blood poisoning.

Ammonia should be used to remove acids from carpets, clothes, or hands, and to counteract stings of insects.

Mustard and warm water, taken internally, is a good emetic, in cases of poisoning.

Vinegar taken internally will counteract the action of caustic potash, caustic soda, or ammonia.

Baking soda, or even the plaster from the wall, taken internally, will stop the action of all acids.

Table salt will prevent excessive harm from silver nitrate (lunar caustic).

White of eggs, milk, and gelatinous drinks should be given in most cases of poisoning, as they tend to coat the lining of the stomach, as well as to form insoluble compounds with many poisons. Encourage vomiting by mustard and warm water. *Send for a doctor at once.*

Besides the household materials, every home should have on hand a few remedies such as corrosive sublimate, tincture of iodine, alcohol, and arnica. All of these are poisons if taken internally.

A solution of corrosive sublimate, made by dissolving one tablet in a pint of water, is the very best antiseptic wash for cuts or bruises. It kills any microorganisms which may enter, and allows new tissue to be built without loss of time.

Tincture of iodine may be used in the place of a mustard plaster and for sprains.

Arnica and alcohol may be used for sprains and lameness, and alcohol may be rubbed on the skin, after a hot bath, to prevent a person from catching cold. See Section 11, First Aid to the Burnt.

References: —

1. 1501: 148-154. Drugs and Poisons.
2. 1503: 417-418. Narcotics.
3. Farmers' Bulletin No. 86. Thirty Poisonous Plants.
4. Farmers' Bulletin No. 188. Weeds Used in Medicine.

5. Farmers' Bulletin No. 377. Harmfulness of Headache Mixtures.
6. Farmers' Bulletin No. 393. Habit-forming Agents.
 - a. 1505 : 132-135. Headaches. — Drugs.
 - b. 1506 : 95-96. Results of Overheating. — Alcohol.
 - c. 1507 : 56-61. Water. — Alcohol.
 - d. 1507 : 163-164. Fainting. — The Effect of Drugs.
 - e. 1509 : 331-335. Poisons, Drugs, and Chemicals. — Antidotes.
 - f. 1509 : 335-342. Fainting, Sunstroke, Drowning, and Choking.
 - g. 1511 : 371-379. First Aid to the Injured.

209. READING METERS

Water, gas, and electric meters are all read in the same manner. The dials are read from left to right, taking the number which the hand, or indicator, has *passed*. If there is doubt, read the next dial. If this indicates 8, 9, or 0, the number in the preceding dial has not been passed. If, however, the next dial reads, 1, 2, or 3, the number has been passed.

The number over each dial shows the total amount which one revolution of the hand in that dial would indicate. Thus if the number is 10,000, it means that one revolution of the hand would indicate 10,000. If the hand indicates 6 in that dial, it means 6000.

Gas is measured in cubic feet, water in gallons or cubic feet (one cubic foot equals seven and one-half gallons), and electricity in kilowatt hours. The unit of measurement does not affect the reading. To find the amount of gas, water, or electricity which has passed through the meter, subtract the previous reading from the last reading.

EXPERIMENTS FOR THE HOME

Leaks in the pipes or wires may be made known by reading the meters carefully and then not using any gas, water, or electricity during the test. The amount of water which is used on a lawn can be measured and some idea obtained of the amount of water which is necessary for keeping a lawn in good condition. One gas burner, or one electric light, may be burned, and the cost per hour may be reckoned. It can be shown that a gas burner which blows gives less light and consumes more gas than does a burner which burns quietly. Similarly, an electric lamp which burns dimly uses nearly as much electricity as a lamp burning to full candle power.

References: —

1. 1803 : 80. The Gas Meter.

210. ECONOMY

There is a certain amount of waste in all food; clothing cannot be made without a loss of some of the cloth; wear is taking place in everything all the time; heat is lost from houses through ventilation; and there is a constant tendency for all the material which is available to man to become unavailable. Some of the waste may be prevented or diminished by care and by the application of knowledge. This is economy.

Sometimes an apparent saving of money is a loss in the end. When we consider that all animal heat is produced by the slow combustion of food, we shall see how erroneous is the idea that a cheap barn is good enough for stock. If the horses and cattle are not warm, they must eat more food and must change their food into heat within their systems, and

therefore, it costs the owner more for food. Again, all food which cattle use to maintain their animal heat, means so much less milk. Milk is produced after all the other animal needs are satisfied; and it might be said in this connection that hens, well cared for, produce more eggs for the same reason, viz. that eggs will not be produced until all other necessities of the body are supplied. The wise farmer builds tight barns to protect his stock from cold weather. He reaps his reward in a larger amount of products.

A few of the household economies may be mentioned: the use of fireless cookers, slow boiling after boiling is established, home bleaching and dyeing, recooking of food to make palatable dishes, sifting of ashes where anthracite coal is used, the home making of soap from refuse grease, the keeping of hens in country places, which may be fed for the most part with waste food, and the use of roasts rather than fried meats. Every housekeeper could save much in buying food if she made a study of food values. See Section 191, Food and Nutrition.

References: —

1. 1503 : 323-325. Food Economy and Waste.
2. 1702 : 359-361. Comparative Cost and Value of Grains.
3. 1702 : 382-383. Economy in Food Values.
4. 1710 : 308-321. Economy in Food and Fuel.
5. Farmers' Bulletin No. 391. Economical Use of Meat in the Home.
6. Reprint from Yearbook Department of Agriculture for 1908: The Wastes of the Farm.
 - a. 1701 : 333. Dyeing.
 - b. 1704 : 280-281. Dyeing.
 - c. 1712 : 307-314. Bleaching and Dyeing.

Experiment 92. — Dyeing.

Apparatus: Burner, asbestos mat, ring stand, two beakers 100 c.c., test tubes.

Materials: Logwood solution, aluminum sulphate solution, 1-20, ammonium hydrate solution, 1-4, two pieces of white cotton cloth 2"×2".

a. Wash a piece of the cotton cloth in several changes of water, and then boil it in the logwood solution for five minutes. Remove the cloth and wash it. Result?

b. Wash another piece of cloth as before, dip it into the aluminum sulphate solution, wring and dip it into the ammonium hydrate solution. Squeeze out the excess of liquid, and boil the cloth for five minutes in the logwood solution. Try washing out the color with soap and water. Is it "fast"?

The ammonium hydrate and the aluminum sulphate together form what is called a *mordant*. This clings to the cloth and also holds the coloring matter fast. Silk and wood "take" the dyes and do not require mordants. There are some dyes which do not require mordants, even with cotton. These are called *direct dyes*.

211. EDUCATION AND CIVILIZATION

Education is more than the acquisition of information. The latter may satisfy our immediate want; the former should supply all of our mental needs. The basis of education, however, is information, but information should be so related to what we already know that it will fit in with it and become part of a connected whole. Otherwise, the information is either lost or becomes part of a jumbled mass in an unorganized brain. In order to learn one thing well, it is necessary that we know a little about a great many things. We cannot

learn one thing alone, other than a fact, for all knowledge is one knowledge.

The uncivilized races know how to do a great many things; they know very seldom why they do such things. Customs and usages are their masters. Nature controls them, and they are helpless under unfavorable conditions of weather or health. There are no connecting links to bind their bits of knowledge together, and reasoning power has not developed. Superstition is common, and their religion is based upon sacrifices by which the gods may be propitiated.

Education is the greatest civilizing factor. It leads us to a fuller appreciation of life in its entirety. It destroys superstitions and stimulates ambition toward better living. While there are educated men who are criminals, education did not make them so, and a more complete education, extending back into their parents' lives, could have prevented the crimes. When education has advanced far enough, there will be no sin, but the education must be general, unlimited by faith or creed, undimmed by prejudice or narrowness.

References: —

1. 1501 : 398. A Long Life.
2. 1503 : 11-13. Science and Matter. — Classification of Facts.
 - a. 1303 : 364-367. Geographical Factors in the Life of Civilized People.
 - b. 1311 : 346-370. The Earth and Man.
 - c. 1904 : 187. Educating the Public.

212. MANNER OF LIVING

The worth of a man to the world and to himself is according to his manner of living. One who only works a little,

eats a little, and sleeps a little is not far removed from the animal state of existence. An animal exists, but, just in so far as it shows intelligence, it lives. Yet the life of a man holds possibilities far beyond that of any animal.

The difference between a workman and an artisan is that the real artisan takes a pride in his work, enjoys it, and tries to improve methods and results. The workman performs his labor as part of the day's program, — a necessary evil, — and is no better at the end of a year than at the beginning. There are many artisans among the so-called workmen, and also many workmen among the self-styled artisans. A man is what he does, irrespective of the world's classification.

A man who tries to live up to his possibilities must be a producer — the world must be better for his life. In order to make manifest one's ability and give opportunity for development and productivity, education is necessary. To know only how to perform certain work produces workmen; to know the reason why certain work is performed in a certain manner, as well as knowing how to do it, gives to the world a man who can improve methods, for he understands the advantages and disadvantages of the old. He becomes a benefactor — an artisan.

Necessity has been said to be the mother of invention, but educated laziness — a desire to accomplish something better with less unnecessary drudgery — will do much toward the more civilized living of mankind. He who can show the method of attaining a given end with less work and time, makes the world a better place in which to live. He who is awake to the possibilities of life truly lives.



APPENDIX

APPARATUS AND MATERIALS

These lists contain the approximate amount of equipment which would be required by a class of ten, with the exception of some pieces of apparatus which are to be used only by the teacher.

APPARATUS

- 10 Alcohol lamps, with collar.
- 10 Asbestos boards, 5" \times 5".
- 2 Balances, Harvard, with weights, 500 g.
- 1 Ball, iron, with screw eyes.
- 10 Battery jars, 6" \times 8".
- 2 doz. Beakers, 50 c.c., high with lip.
- 2 doz. Beakers, 100 c.c., high with lip.
- 1 doz. Beakers, 150 c.c., high with lip.
- 1 doz. Beakers, 200 c.c., high with lip.
- 10 Bells, electric, 3".
- 5 Boards, 3' \times 5" \times $\frac{1}{8}$ "; narrow strip along edge.
- 10 Bottles, wide mouth, 500 c.c.
- 4 doz. Bottles, wide mouth, 250 c.c.
- 1 Brass tube, 6" \times 1".
- 10 Bristol boards, 22" \times 28".
- 10 Bunsen burners.
- 10 Calorimeters, 3" \times 1".
- 1 Cannon, small.
- 2 doz. Cells, dry.
- 10 Chalk boxes.
- 4 doz. Chimneys, Argand or student.
- 1 doz. Clay pipes.
- 2 lbs. Coal, soft.

- 1 Coil, induction $\frac{1}{4}$ " spark.
- 5 each Colored cards, red, bluish green, yellow, blue, purple.
- 10 Copper rods, #12, 6".
- 1 doz. Crystallization dishes, 5".
- 2 doz. Evaporation dishes, 3".
- 1 doz. Files, 4" medium.
- 2 doz. Flasks, 250 c.c.
- 1 doz. Funnels, 3".
- 4 doz. Glass plates, 4" \times 4".
- 1 doz. Glass tubes, 8" \times $\frac{1}{2}$ ".
- 1 doz. Globes, 6".
- $\frac{1}{2}$ doz. Graduates, 100 c.c.
- 1 Hammer.
- 1 doz. Holders, test tube.
- 10 Iron rods #12, 6".
- 1 Preserve jar, 1 pint.
- 2 Kipp generators, 1 pint.
- 1 Lamp, electric, in socket, with cord and plug.
- 20 Lead strips, 5" \times 1" \times $\frac{1}{16}$ ".
- 10 Magnets, bar, 6".
- 10 Magnetic needles, 4".
- 1 doz. Medicine droppers.
- $\frac{1}{2}$ doz. Meter sticks.
- 2 doz. Mirrors, 5" \times 2".
- 1 paper Needles #5.
- 10 Pans, bread, 12" \times 6" \times 3".
- 1 paper Pins.
- 2 doz. Pith balls.
- 10 pieces Platinum wire #30, 6".
- 1 doz. Porous cups, 4" \times 2".
- 10 Prisms, 60°, 3" \times 1".
- 10 Protractors, 4".
- 10 Ring stands, 2" \times 5" rings and clamps.
- 1 gr. Rivets, brass, for paper, $\frac{1}{2}$ ".
- 10 Rubber rods.
- 2 doz. Rubber stoppers, 1", one hole.
- 2 doz. Rubber stoppers, 1", two holes.
- 1 doz. Rubber stoppers to fit bottles.

- 50 ft. Rubber tubing, $\frac{1}{4}$ ".
- 1 doz. Saucers, enamelled.
- 2 pairs Scissors.
- 10 pairs Screw eyes, iron, one to fit inside the other.
 - 1 Spool silk thread, #00.
 - 10 Spring balances, $\frac{4}{2000}$ g.
 - 2 Springs, clock.
- 10 Sticks, 30" \times 1" \times $\frac{1}{2}$ ".
- 20 Sticks, 60" \times $\frac{1}{2}$ " \times $\frac{1}{2}$ ".
- 1 doz. Stirring rods, 8" \times $\frac{3}{16}$ ".
- 10 Supports for magnets, wood.
- 10 Syringe bulbs, valves and tubes at both ends.
- 10 Table tumblers.
- 1 gr. Test tubes, 6" \times $\frac{3}{4}$ ".
- $\frac{1}{2}$ gr. Test tubes, 8" \times 1".
- 3 doz. Test tubes, 8" \times 1", hard glass.
- 10 Thermometers, all glass (- 10° to 225° F.).
- 10 Thermometers, all glass (- 20° to 110° C.).
- 2 doz. Thistle tubes, 8".
- 5 Thistle tubes with stop cock.
- 4 doz. U-tubes, diameter 1", with side tubes.
 - 1 Vise, 3" jaws.
- 10 Water traps.
- 10 pieces Window glass to fit chalk box.
- 2 lb. Wire copper, #20, insulated.
- $\frac{1}{2}$ lb. Wire, German silver, #22, insulated.
- 1 lb. Wire, iron, #30.
 - 20 Wood blocks, 5" \times 2" \times 2".
 - 10 Wood blocks, 3" \times 3" \times 1", with peg 6" \times 1".
 - 20 Wood blocks, 3" \times 2" \times 1".
 - 10 Wood blocks, 2" \times 1" \times 1", slotted.
 - 10 Wood blocks, 6" \times 3" \times 1".

MATERIALS

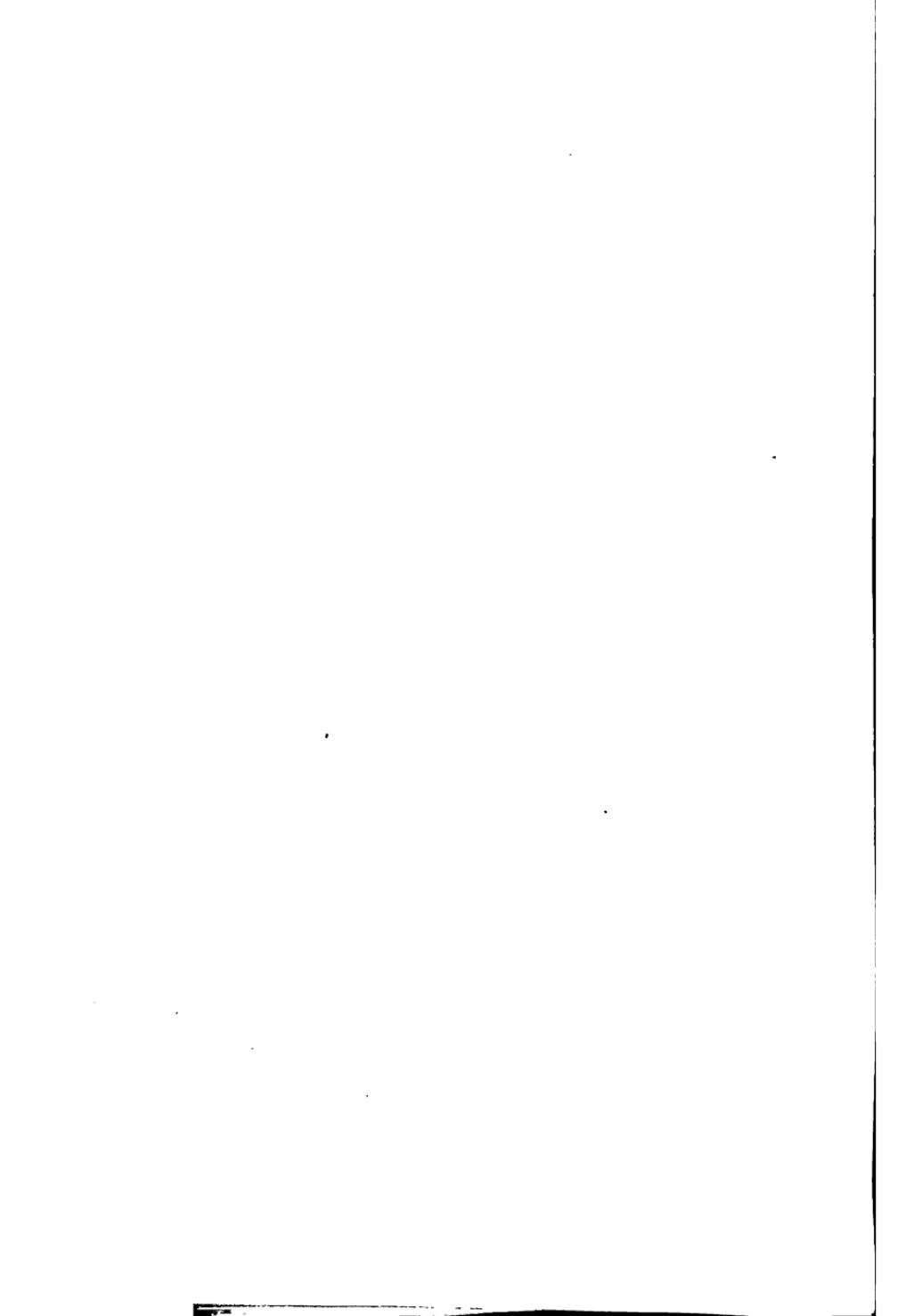
- 1 pt. Alcohol.
- $\frac{1}{4}$ lb. Aluminum.
- 1 lb. Ammonium chloride.

- 4 lbs. Ammonium hydrate.
- 2 lbs. Ammonium nitrate.
- 2 lbs. Ammonium sulphide.
- $\frac{1}{4}$ lb. Asbestos paper, thin.
- $\frac{1}{4}$ lb. Barium chloride.
- $\frac{1}{4}$ lb. Barium sulphate.
- $\frac{1}{2}$ lb. Beeswax.
- 1 pt. Benzine.
- $\frac{1}{2}$ doz. sheets Blotting paper, 22" \times 28".
- $\frac{1}{4}$ lb. Bromine.
- $\frac{1}{2}$ lb. Calcium chloride, granulated.
- $\frac{1}{4}$ lb. Camphor.
- 3 doz. Candles, 6" \times 1".
- 1 Carbon dioxide tank, 5 lbs.
- 1 doz. sheets Cardboard, heavy, 22" \times 28".
- $\frac{1}{2}$ lb. Castile soap, powd.
- 1 lb. Chalk, powd.
- 1 doz. Charcoal blocks for blow-piping.
- 1 lb. Charcoal, wood, small pieces.
- $\frac{1}{4}$ lb. Chloroform.
- 1 doz. pieces Cigar box wood, 6" \times 4".
- 5 lbs. Clay.
- $\frac{1}{2}$ doz. pieces Cloth, red, yellow, blue.
- 1 doz. pieces Copper, 6" \times $\frac{1}{2}$ " \times $\frac{1}{16}$ ".
- 1 doz. pieces Copper, 6" \times $\frac{1}{2}$ " \times $\frac{1}{16}$ ".
- 5 lbs. Copper sulphate.
- $\frac{1}{4}$ lb. Coral.
- 4 doz. Cork stoppers, 1".
- 1 doz. each Cork stoppers, Argand size, top and bottom.
- 1 doz. Cork stoppers for porous cup.
- 1 doz. Cork stoppers, flat and thin, 1".
- $\frac{1}{4}$ lb. Cotton, absorbent.
- 1 box Elastic bands, assorted.
- 1 lb. Ether.
- $\frac{1}{2}$ lb. Ferric chloride.
- 1000 Filter papers, 5".
- 1 pt. Fish oil.
- $\frac{1}{4}$ lb. Formaldehyde.

- 1 pt. Gasoline.
- 5 lbs. Glass tubing, $\frac{1}{4}$ ".
- 2 qts. Grape juice.
- 3 lbs. Grape sugar.
- 1 oz. Gun cotton.
- $\frac{1}{4}$ lb. Gunpowder.
- 4 lbs. Hydrochloric acid.
- 1 oz. Iodine.
- 1 piece Iron picture cord.
- 3 lbs. Iron turnings.
- 1 qt. Kerosene.
- 5 lbs. Lead, in bulk.
- 2 lbs. Lead nitrate.
- 3 lbs. Lead carbonate, basic.
- 1 lb. Limestone.
- 1 qt. Linseed oil, boiled.
- 3 lbs. Litharge.
- 1 doz. sheets Litmus paper, blue.
- 1 doz. sheets Litmus paper, red.
- 2 oz. Litmus, cubes.
- $\frac{1}{2}$ lb. Logwood, chips.
- $\frac{1}{4}$ lb. Magnesium ribbon.
- 5 lbs. Manganese dioxide, granulated.
- 5 lbs. Marble, broken.
- 5 lbs. Mercury.
- $\frac{1}{2}$ lb. Mercuric oxide.
- 1 qt. Molasses.
- 3 sq. ft. Mosquito netting.
- 1 pt. Naphtha.
- 4 lbs. Nitric acid.
- 1 pt. Olive Oil.
- $\frac{1}{2}$ lb. Oxalic acid.
- 2 lbs. Paraffin.
- 1 oz. Pepsin.
- 1 qt. Petroleum, crude.
- 1 oz. Phenolphthalein.
- $\frac{1}{4}$ lb. Phosphorus.
- $\frac{1}{4}$ lb. Pitch.

- $\frac{1}{2}$ lb. Potassium bromide.
- 3 lbs. Potassium chlorate.
- $\frac{1}{4}$ lb. Potassium iodide.
- 1 lb. Potassium nitrate.
- $\frac{1}{2}$ lb. Potassium permanganate.
- 2 lbs. Red lead.
- 1 lb. Rice.
- 1 lb. Rochelle salts.
- 1 lb. Rosin.
- 3 lbs. Salt.
- 5 lbs. Sand.
- $\frac{1}{2}$ doz. sheets Sand paper, #0.
- $\frac{1}{2}$ lb. Sawdust.
- 1 oz. Silver nitrate.
- 1 lb. Sodium bicarbonate.
- 2 lbs. Sodium carbonate, crystals.
- $\frac{1}{4}$ lb. Sodium (metallic).
- 2 lbs. Sodium hydrate, solid.
- 2 lbs. Sodium peroxide, in cubes.
- 2 lbs. Sodium sulphate, crystals.
- 1 lb. Starch, corn.
- 1 lb. Starch, potato.
- $\frac{1}{2}$ lb. String.
- 3 lbs. Sugar.
- 9 lbs. Sulphuric acid.
- 2 lbs. Sulphur, powd.
- 2 sheets Turmeric paper.
- 1 pt. Turpentine.
- $\frac{1}{2}$ lb. Venice turpentine.
- 2 lbs. Whiting.
- Yeast.
- 1 lb. Zinc, granulated.
- 10 Zinc strips, $6'' \times 1'' \times \frac{1}{16}''$.
- 2 lbs. Zinc oxide.

THE following pages contain advertisements
of Macmillan books on kindred subjects



MACMILLAN'S COMMERCIAL SERIES

EDITED BY CHEESMAN A. HERRICK

President of Girard College, formerly Director of School of Commerce, Philadelphia
Central High School

Each volume 12mo, cloth

The Meaning and Practice of Commercial Education. By the Editor. xv +
378 pages. \$1.25 net.

The Geography of Commerce. By SPENCER TROTTER, M.D., Professor of
Biology and Geology in Swarthmore College, Pa. xxiv + 410 pages.
\$1.10 net.

Commercial Correspondence and Postal Information. By CARL LEWIS ALTMAYER,
Drexel Institute, Philadelphia. xiv + 204 pages. 60 cents net.

Comprehensive Bookkeeping: A First Book. By ARTEMAS M. BOGLE, Head
of Department of Mathematics, High School, Kansas City, Kansas. xi +
142 pages. 90 cents net.

Bookkeeping Blanks. By ARTEMAS M. BOGLE. Four numbers. 75 cents a
set net.

Teacher's Manual to Accompany Comprehensive Bookkeeping. By ARTEMAS
M. BOGLE. vi + 75 pages. \$1.00 net.

Elements of Business Arithmetic. By ANSON H. BIGELOW, Superintendent of
Schools, Lead, South Dakota, and WILLIAM A. ARNOLD, Director of Business
Training, Woodbine (Iowa) Normal School. xv + 254 pages.

The volumes of MACMILLAN'S COMMERCIAL SERIES named
below are in preparation and other volumes will follow:

The History of Commerce. By the Editor of the Series.

Applied Arithmetic for Secondary Schools. By ERNEST L. THURSTON, District
Superintendent of Schools, Washington, D.C.

PUBLISHED BY

THE MACMILLAN COMPANY

64-66 Fifth Avenue, New York

BOSTON

CHICAGO

DALLAS

SAN FRANCISCO

MACMILLAN'S COMMERCIAL SERIES

The Idea of the Series

This series is prepared in the belief that disciplinary education can be secured through the use of *subject-matter of practical worth*. Much that is fixed in our system of education is retained and given new application; new elements are introduced and are properly related to the old. In brief, the plan is to modernize the instruments of instruction and make schools more effective as a preparation for present economic life. The best from foreign books has been utilized for suggestion; the best in our educational development is preserved. The *plan and its execution* are the work of experienced teachers. The books are products of specialists, working under the general supervision of the editor. Each volume is adequate to its subject, authoritative, and supplied with a working equipment such as illustrations, maps, and diagrams.

Elements of Business Arithmetic

By ANSON H. BIGELOW, Superintendent of Schools, Lead, S.D., and
WILLIAM A. ARNOLD, Director of Business Training, Woodbine (Iowa)
Normal School.

Cloth. 12mo. xv + 254 pages.

The preparation of this text was undertaken in the belief that the arithmetic of the grammar school and of the commercial course of the high school should teach the methods most in vogue in the business world, and that those methods should be so taught as to form correct habits in those who are to attack the problems of real life. It is distinctly a business arithmetic, presenting the minimum of theory and the maximum of practice in business methods. Various methods are presented, but only those used in practical business computations. The topics treated, by chapters, are: addition and subtraction, multiplication and division, decimals, fractional parts (short methods), fractions, measures (length, area, volume, time, weight, and value), French metrical system, percentage, trade discount, commission, taxes and duties, interest, banking and discount, stocks and bonds, insurance, proportion, proportional parts, and partnership. These subjects are chosen with reference to business needs and they are treated in such a manner as to give the pupil the largest possible amount of drill in practical business methods. The book purposely brings the work of the school and the needs of common life into vital connection. It is suitable for use in the grammar school and in the commercial courses of the high school.

PUBLISHED BY

THE MACMILLAN COMPANY

64-66 Fifth Avenue, New York

BOSTON

CHICAGO

DALLAS

SAN FRANCISCO

The Meaning and Practice of Commercial Information

BY CHEESMAN A. HERRICK

The book above mentioned explains the idea and describes *the actual workings of commercial schools*. It treats commercial education from various points of view, and shows that this form of instruction is a result of present economic conditions and a natural step in our educational development. The author shows also that special education for the present commercial age is both possible and desirable, and that such education will gradually bring about a higher form of commercialism.

The work reviews the movements to furnish commercial education in leading countries. For the United States a series of chapters are devoted to the Private Commercial School, the High School of Commerce, the Curriculum of the Secondary Commercial School, and the Higher School of Commerce. Numerous illustrations of men and institutions are furnished.

An appendix supplies a good number of curricula for schools of various grades. The value of the work is further increased by a select bibliography of the subject.

The Geography of Commerce

BY SPENCER TROTTER, M.D.

This book is exceptionally fortunate as well as unique in its authorship. Dr. Trotter is a scientist and geographer of high standing, while the editor, Dr. Herrick, is a trained economist. Both are experienced and successful teachers. The text has stood the test of work with high school students.

The Geography of Commerce gives a clear presentation of existing conditions of trade. Throughout the book emphasis is laid on the relation between physiography, climate, etc., and the activities and the organizations of men. As a result, the book is on the "practical side" of geography. Trade relations between the United States and other countries are given special prominence. The causal relations of physical environment to men, of men and environments to products, and of products to trade, are treated with a unity that makes the book admirably suited to class use.

A complete working equipment and a list of books for further consultation are furnished. Supplementary questions and topics are also supplied.

PUBLISHED BY

THE MACMILLAN COMPANY

64-66 Fifth Avenue, New York

BOSTON

CHICAGO

DALLAS

SAN FRANCISCO

Commercial Correspondence and Postal Information

BY CARL LEWIS ALTMAIER

Mr. Altmaier's work supplies two present needs, a text-book for school use and a handbook for office use. In the first place, his book is a *working manual for instruction and practice in letter writing*, and thus it furnishes material for practical English composition. Correct forms of letters are furnished, after which the learner is asked to deal with situations of the kind actually met with in business correspondence. The treatment of correspondence is supplemented by a somewhat *detailed account of postal arrangements*, both domestic and international. The book is illustrated with photographs of documents, reproductions of actual letters, and a postal map of the world.

Comprehensive Bookkeeping

BY ARTEMAS M. BOGLE

A few of the points that commend this volume are:

1. The gradual and systematic development of the subject.
2. Preliminary sets for drill followed immediately by more concrete sets for the more advanced work of the student.
3. Material so arranged that the teacher may use it largely in his own way.
4. The sets so arranged that short exercises or longer ones may be given as may be most advantageous.
5. Provision for drill on important points and at the place where needed, thus insuring the mastery of each point.
6. Arrangement such that at almost any stage previous points may be reviewed without going back and working over the old material.
7. Clear, concise explanations.
8. A large number of cross references, showing the connection of one portion of the subject with another.

Teacher's Manual to Accompany Comprehensive Bookkeeping

BY ARTEMAS M. BOGLE

This book contains the results of computations required by the regular series of exercises given in Bogle's "Comprehensive Bookkeeping." These tables, giving the "answers" which should be right, save the teacher labor in checking up pupils' results. The forms are not intended for models but only as results to save labor by the teacher.

PUBLISHED BY

THE MACMILLAN COMPANY

64-66 Fifth Avenue, New York

BOSTON

CHICAGO

DALLAS

SAN FRANCISCO



